SCHOOL OF CIVIL ENGINEERING

INDIANA DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY RESEARCH PROJECT

FHWA/IN/JHRP-93/2
Final Report

PAVEMENT DRAINAGE AND PAVEMENT-SHOULDER JOINT EVALUATION & REHABILITATION

Zubair Ahmed
T. D. White
P. L. Bourdeau

PURDUE UNIVERSITY

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by

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Joint Highway Research Project

Project No.: C-36-15J
File No.: 6-9-10

Prepared as Part of an Investigation
Conducted by the
Joint Highway Research Project
Engineering Experiment Station
Purdue University

In cooperation with the
Indiana Department of Transportation
and the
U.S. Department of Transportation
Federal Highway Administration

Department of Civil Engineering
Purdue University
West Lafayette, Indiana 47907

March 1993
Revised February 1994

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FHWA/IN/JHRP-93/2	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle PAVEMENT DRAINAGE AND PAVEMENT-SHOULDER JOINT EVALUATION AND REHABILITATION		5. Report Date March 1993 6. Performing Organization Code
7. Author(s) Zubair Ahmed, T. D. White and P.L. Bourdeau		8. Performing Organization Report No. JHRP-93/2
9. Performing Organization Name and Address Joint Highway Research Project Civil Engineering Building Purdue University West Lafayette, Indiana 47907		10. Work Unit No. 11. Contract or Grant No. Indiana-HPR-2018
12. Sponsoring Agency Name and Address Indiana Department of Transportation State Office Building 100 North Senate Avenue Indianapolis, Indiana 46204		13. Type of Report and Period Covered Draft Final Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The objectives of this research were i) to evaluate the performance of pavement subdrainage systems ii) study the behavior of moisture conditions below pavements and iii) provide recommendations for improved drainage criteria based on analysis of field data.

Existing and retrofitted subdrainage collector systems were inspected through external visual inspection in combination with a probe for internal inspection. Distresses and deficiencies in construction observed were listed and compiled on video. A methodology for inspection is presented that can be used by highway agencies in monitoring the condition, need for maintenance, and performance of collector systems.

Pavements with various types of subdrainage systems were instrumented to monitor the effects of different parameters influencing flow. The instrumentation package included pressure transducers, moisture blocks, thermistor probe, rain gauge, tipping bucket flow meter and a data recording and storage system. Laboratory investigations were conducted on subgrade and subbase samples collected from instrumented sites to assess their material and hydraulic properties. Parameters obtained by fitting Brooks & Corey's model and Van Genuchten's model to experimental data have shown good correlations with measured values.

Data collected from instrumented sites show varying response rate and time of outflow with respect to precipitation for different types of pavements and collector systems. Statistical Analysis has shown significant influence of base permeability in addition to pavement and drain types on pavement outflow. High correlations exist between precipitation and pore pressure underneath pavements. Data from instrumentation and laboratory tests will help in calibrating and validating an analytical seepage program developed separately as part of this research project.

17. Key Words pavement subdrainage, collector systems, inspection, instrumentation permeability, precipitation, outflow, seepage program		18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, CA 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-69)

ACKNOWLEDGEMENTS

The authors wish to acknowledge the Program Development Division, the Research and Training Center, and the Materials and Test Division of Indiana Department of Transportation for providing invaluable assistance during the data gathering and planning phase of the research. Special thanks are due to Mr. David Andrewski, Mr. Firooz Zandi and Ms. Becky McDaniel of INDOT for their assistance and advice in this study. Additionally, thanks are due to the District Offices of Crawfordsville, Fort Wayne, Greenfield, Laporte and Vincennes for their help during pavement instrumentation.

Thanks are extended to Dr. Eileen Kladivko and Cliff Keifer of the Agronomy Department, and to Tom Cooper of the Civil Engineering Department for their help in laboratory testing and field instrumentation activities. Special thanks go to Dr. Ahmed El-Sharief for sharing information on fin drains and conceiving the idea of the constant head head permeameter, and to Dr. T. Kuczek and Dr. C. F. Scholer for offering valuable input at various times during the study.

The financial support for this research project was provided by the Federal Highway Administration and the Indiana Department of Transportation through the Joint Highway Research Project, Purdue University, West Lafayette, Indiana.

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LIST OF ABBREVIATIONS

Abbreviation	Description
AADT	Average Annual Daily Traffic
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transporation Officials
APTM	Asphalt Treated Permeable Material
ASTM	American Society For Testing And Materials
BSOG	Bituminous Stabilized Open Graded
FHWA	Federal Highway Administration
FPTD	Field Permeability Testing Device
GLM	General Linear Model
IDOH	Indiana Department of Highways
INDOT	Indiana Department of Transportation
NCHRP	National Co-operative Highway Research Program
NSOG	Non-stabilized Open Graded
OECD	Organization for Economic Co-operation and Development
OGDL	Open Graded Drainage Layer
PCC	Portland Cement Concrete
PCI	Pavement Condition Index
Penn DOT	Pennsylvania Department of Transporation

Abbreviation	Description
PFED	Prefabricated Edge Drain
TDR	Time-domain Reflectometry
USGS	United States Geological Survey
WASHO	Western Association of State and Highway Officials

IMPLEMENTATION REPORT

An extensive field inspection of subsurface edge drains in Indiana was carried out through visual observations and use of camera systems for internal inspection. The investigation pointed out numerous problems and distresses which result in poor performance of edge drain systems. These included improper construction practices, deficiencies in system design, deficiency of presently used prefabricated edge drain product and lack of inspection and maintenance procedures. An inspection methodology was developed which includes a collector system inspection form (attached) to aid in future inspection of edge drain systems by the Indiana Department of Transportation (INDOT). A video has also been prepared showing various inspection process steps and setup of the camera system, which will help in a systematic evaluation of edge drain performance.

An intensive research was conducted in the form of field instrumentation and laboratory investigations to identify the pattern of moisture movement beneath pavements. Data analysis from instrumented sites show outflow to be affected by base permeability and edge cracking. The analysis also indicated high pore pressure buildup in subbase layers in the absence of

a positive drainage system. Laboratory investigations were conducted on ten subgrade soils and five subbase materials to determine material and hydraulic properties.

Based on this research effort, specific recommendations suggested to INDOT for implementation include:

1. Use of the camera system as a post construction inspection tool and for periodic inspections of existing edge drains.
2. Treatment of the area around outlet pipes through rip-rap protection and provision of a minimum of 4 inch freeboard. This will minimize vegetation growth, sedimentation and erosion around the outlet area as well as protect the outlet pipe from damage caused by mowing equipment.
3. Use of a clean-out assembly employing high water pressure to jet clean clogged edge drains, especially on flat grades. This will assist in preventing pumping and other forms of distresses to occur in the pavement subbase, through reduced pore pressure buildup.
4. Use of an improved prefabricated edge drain product as the type of fin drain inspected in this study has a tendency to buckle under load.
5. To facilitate cleaning and inspection, Y or L outlet to pipe connections be used, and no T-connections be allowed.

6. Use of a filter material as trench backfill instead of recompacted excavated earth to prevent external caking and internal clogging of edge drains.
7. Proper sealing of pavement-shoulder joints to reduce moisture infiltration and use of a permeable subbase to rapidly remove entrapped water is recommended.
8. Use of developed hydraulic parameter values of subgrade soils and subbase materials with PURDRAIN program.
9. Incorporation of the findings of this research into appropriate INDOT specifications and guidelines for improved subdrainage performance.

For further questions or information, contact Zubair Ahmed at (317)494-6243 or Prof. T. D. White at (317)494-2215 or Prof. P. L. Bourdeau at (317)494-5031.

CHAPTER 1 - INTRODUCTION

Problem Statement

Moisture accumulation in pavement base and/or subbase layers, either due to the absence of a positive drainage system or due to the material characteristics of the drainage layer leads to damage, and in some cases, complete failure of the pavement structure. This is true for both asphalt and concrete pavements.

Providing pavements with efficient internal drainage systems significantly reduces water related damages, which not only increases the pavement life, but also minimizes maintenance and rehabilitation costs. Moisture damage is directly related to the length of time moisture is retained in the pavement system. The effect of moisture is significant enough to warrant the inclusion of specific factors in the AASHTO Guide for Pavement Design (1986). These factors apply not only to the design of new pavements, but also to the evaluation of existing pavements.

A research program was developed to obtain information on the performance of subsurface drainage systems. This program included obtaining specific drainage data, developing an analysis procedure, and providing recommendations on materials, inspection and maintenance of subsurface drainage systems.

Research Objectives

The major objective of this study is to assess for the first time, the performance of the contemporary drainage schemes in use, and suggest ways and means of improving the existing drainage systems as well as to provide a tool by which the performance of new and retrofit drainage systems could be evaluated.

The following major areas were studied in detail:

1. study of the conditions and performance characteristics of existing pavement subdrainage systems in Indiana. This involved inspection and condition assessment of various types of pavement subdrainage systems by the use of borehole cameras, and identification of factors involved in the performance of these systems.

2. development of a methodology for inspection of collector systems. Routine inspection would aid INDOT in scheduling maintenance and evaluating long term performance of pavement subdrainage collector systems.

3. development of an analytical model of subsurface systems accounting for different geometric and material characteristics of the sections comprising a pavement system.

4. obtain specific drainage data for calibration and validation of the analytical model through on-site pavement instrumentation.

5. determine in the laboratory, soil-water and other properties of base/subbase materials and subgrade soils for use in the analytical model.

   The third objective is being accomplished by Mr. David Espinoza and is being reported in a separate report (Espinoza et al., 1993).

Outline of Report

With the objectives stated in the previous section, this report is presented in seven chapters. The first chapter states the problem and objectives, while the second chapter

reviews the literature on present state-of-practice for subdrainage evaluation, design and material requirements and pavement instrumentation and inspection techniques.

Chapter three deals with the inspection and condition assessment of existing subdrainage systems in the state through the use of a videoimagescope and a borehole camera, and identification of factors involved in the performance of these systems. A methodology for inspection of collector systems is developed and described in the same chapter.

Chapter four describes the development and implementation of a plan for on-site subdrainage instrumentation on existing pavement sections, with the objective of collecting site specific data for use in the validation of the subsurface drainage computer program as well as in the evaluation of subsurface flow for different conditions.

Chapter five deals with the laboratory testing procedures undertaken to classify subgrade and subbase materials from pavement test sections. The chapter also contains test result values of parameters influencing flow in the drainage layer.

Chapter six uses the results of data collected from on-site instrumentation in making statistical and engineering analyses of the influence of various factors on pavement drainage. Finally, in Chapter 7 the summary and conclusions of the study are presented.

CHAPTER 2 - LITERATURE REVIEW

There is significant literature available on various aspects of subdrainage. Cedergren and O'Brien (1971) have listed 225 abstracts related to pavement subdrainage. Dempsey, Darter and Carpenter (1971) have presented a comprehensive state-of-the-art review of existing literature and current practices pertaining to subdrainage and moisture movement in pavement systems. Within the scope of this report, only the salient points from selected publications are summarized. The review deals with the historical development of drainage practice, field and laboratory studies conducted specifically with respect to the development of drainage layers and materials and moisture movement in pavement systems.

Historical Review

The benefits of rapid internal drainage of pavements and the detrimental effects due to its absence have been known since the early part of 16th century. Bruce (1932) credits Tresaguet with first applying a scientific approach to road improvement in France about 1764. He specified a base layer of large stones covered with a thin layer of smaller stones to provide better subsurface drainage.

John L. Macadam (1820) in an address to the London Board of Agriculture commented that: "If water passes through a road and fills up the native soil, the road, whatever its thickness, loses support and goes to pieces". Various types of pavements carrying his name and based on his philosophy have been built and used over the years. This philosophy still guides pavement design and construction in many areas of the world.

J.W. Gregory (1931) stated the chief source of weakness in a road to be stagnant water. He advocated the use of coarse, closely packed gravel as a foundation for ordinary roads, reasoning that it distributed the weight of the road evenly on the underlying material and was easily drained.

Two well known road tests, the WASHO Road Test (1955) and the AASHO Road Test (1962) proved that excess water was the prime factor in the failure of pavements, with the damage to pavements being greater in wet periods than in dry.

Highway researchers and practitioners are in agreement on the effect of water on pavement distresses (Yoder,1946; Barenberg et al.,1974; OECD,1978). In flexible pavements, the continued presence of moisture in conjuction with heavy vehicle loads may result in stripping of asphalt from aggregate, potholes and alligator and cracking. In concrete pavements, moisture may result in loss of support, degradation of the base material and concrete deterioration.

The major distress associated with absence of subdrainage in concrete pavements is 'pumping'. Trapped water in conjunction with moving wheel loads on the pavement surface produces high pore pressures in the base/subbase layers of the pavement system. If not dissipated within a reasonable time frame, such pressures cause pumping of material from the base and ultimately failure of the pavement.

Van Wijk and Lovell (1984) identified water in the pavement as one of the three components necessary for pumping in concrete pavements to occur. They also stated the results of a survey, in which almost 60% of the 46 states questioned indicated that pumping is a serious problem.

Figure 2.1 shows the results of a study made by Darter et al. (1983) on the effects of positive drainage on pumping. A low pumping level is reached in only 8 years for a concrete pavement without underdrains, whereas the same section with underdrains takes 30 years to reach the same pumping level. Data from the study indicated that for sections showing high severity pumping, most did not have underdrains (Table 2.1). Dempsey (1982) studied conditions which causes pumping and channeling in pavement systems through field and laboratory studies and concluded that the use of non-erodible base materials and good drainage practices can lead to improved performance of pavements during the design life.

Cedergren (1970, 1973, 1989a) has been a major proponent in emphasizing the design of pavement based on drainability

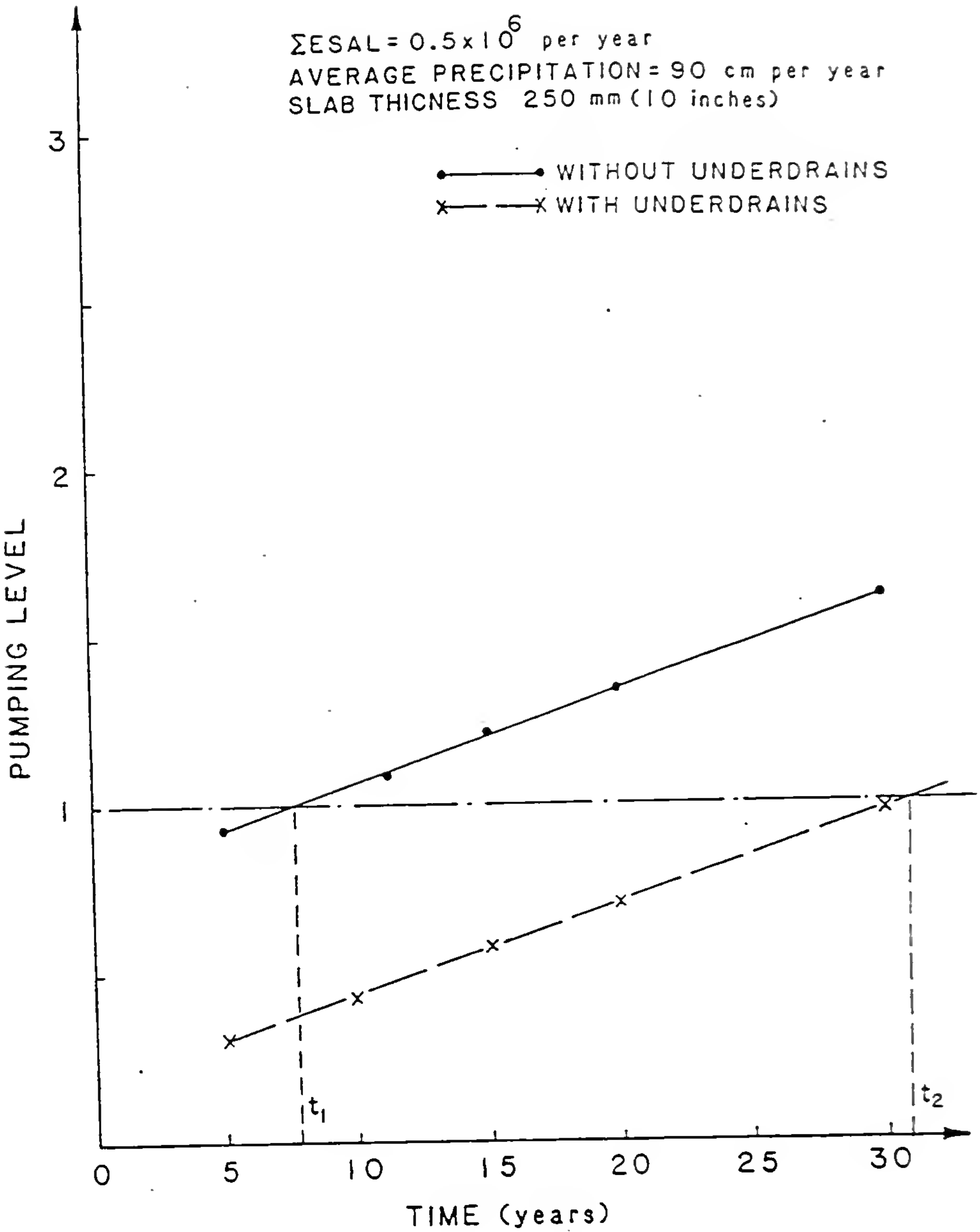


Figure 2.1 Effect of subdrainage on pumping (Darter, et.al, 1983)

Table 2.1 Effect of underdrains and precipitation on pumping (Darter et al., 1983)

Annual Precip. (cm)	UNDERDRAINS PRESENT Cumulative 18-Kip ESAL's 3.0×10^6	 8.0×10^6	 1.6×10^7	Annual Precip. (cm)	NO UNDERDRAINS Cumulative 18-kip ESAL's 3.0×10^6	 8.0×10^6	 1.6×10^7
75	.31	.58	1.03	75	.94	1.22	1.67
100	.35	.63	1.03	100	0.99	1.27	1.71
125	.40	.68	1.12	125	1.03	1.31	1.76

rather than on density and stability. He established the scope and provided the basis for modern subdrainage design for both highway and airfield pavements by describing procedures for estimating water inflows and outflows in pavement systems (Cedergren, 1974; Cedergren et al., 1972). Moulton (1980) presented a detailed analysis and design of highway subdrainage system including material requirements, groundwater control techniques and construction procedures.

Ridgeway (1982) has provided a comprehensive discussion of subsurface drainage design as well as installation of subdrainage as part of pavement rehabilitation projects. Ray and Christory (1989) presented observations conducted on the concrete pavements in the Paris region in France, and recommended full-width drainage layers with a high percentage of voids for satisfactory performance.

Carpenter et al. (1981) have given a procedure for classifying pavements as to the potential for moisture accelerated damage to occur. The analysis aids in evaluating drainage problems of particular materials and in developing maintenance strategies to alleviate moisture related problems. Woodstrom (1983) described improved base designs and pavement drainage systems in California for both new construction and rehabilitation. Majidzadeh (1976) evaluated subsurface drainage conditions underneath concrete pavements in Ohio and indicated that moisture and drainage related problems are quite significant.

When distressed concrete pavements are overlaid with asphalt layers without providing for the removal of entrapped water, the problem persists in the form of wet spots on the overlaid pavement. Figure 2.2 shows a section of Interstate I-64 in Indiana where entrapped water in the pavement started seeping out of the asphalt overlay within one year of construction. Kandhal et al.(1989) have presented three case histories of water damage to asphalt overlays over portland cement concrete (PCC) pavements in Pennsylvania. They found significant amount of free moisture in the pavement layers and damage due to stripping on asphalt overlays. Asphalt treated permeable material (APTM) was proposed to provide an effective subsurface drainage system for new pavements.

Economic studies (Cedergren,1978, Forsyth et al., 1987) have shown that billions of dollars could be saved by the use of good drainage systems. Mathis (1989) has reviewed and compared the practices of ten states on the design, construction practices, use and cost performance of permeable bases. The Asphalt Institute (1966) and Portland Cement Association (1984) have incorporated methods for drainage and erosion analysis as part of the overall design process for flexible and rigid pavements.

Hall et al. (1989) have developed rehabilitation strategies for concrete pavements with consideration of drainage (Figure 2.3), joints and other pavement features. FHWA has conducted a special project (Baumgardner and Mathis,

Figure 2.2 Water seeping from overlaid concrete pavement

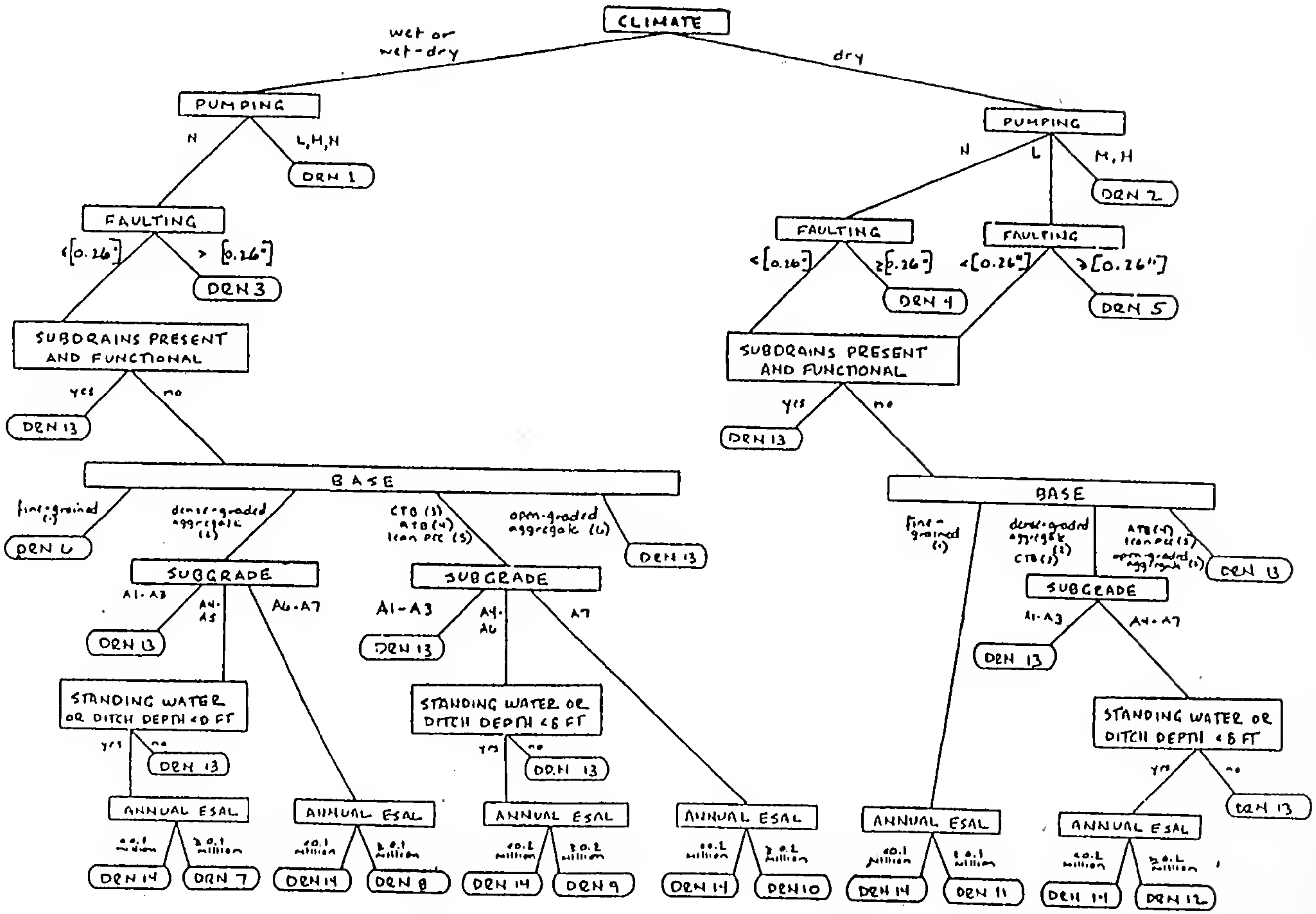


Figure 2.3 Drainage Rehabilitation Decision Tree (Hall et al., 1989)

1989) with the objective to evaluate the effectiveness of retrofit longitudinal edge drains to remove water from PCC pavements. The study will also evaluate various non-destructive methods for monitoring pavement drainage systems.

Elements of Subdrainage

Most of the roads built during the past several decades were built with emphasis on strength and not on drainage for performance. The effect of moisture trapped inside the pavement and its rapid drainage from the system was never given the importance it deserved. This outlook changed in the early 1970's and a significantly different pavement design philosophy with emphasis on drainage was accepted.

The Organization for Economic Co-operation and Development (OECD) (1973) has summarized research work carried out in participating countries to predict moisture content of road subgrades. A number of field and laboratory studies combined with theoretical analysis have been conducted on the material characteristics of elements of subdrainage and on the extrinsic and intrinsic factors which influence subdrainage. A brief review of these studies follow.

Drainage Layers

The use of open graded drainage layers (OGDLs) has gained acceptance as a means of rapidly draining infiltrated water

from pavement structures, and represents a careful balance of permeability and stability of the base course material. These types of base and subbase layers have limited fines. The suggested range of OGDL permeabilities is quite wide, ranging from 1000 ft/day to 20,000 ft/day (Mathis, 1989).

Strohm et al. (1967) conducted laboratory permeability tests on four gradations of base course materials. These tests indicated that the permeability decreased significantly with the increase of density and hydraulic gradient. They concluded that the gyratory compaction procedure developed in the investigation could be used to obtain uniformly prepared specimens for use in the evaluation of drainage characteristics of base course materials.

Barenberg and Tayabji (1974) tested six pavement sections with open-graded bituminous aggregate drainage layers. To simulate infiltration, water was passed through the drainage layers and dynamic loading applied to the test sections. Results from the study indicated a high permeability for the drainage layers.

Smith et.al (1970) reported the findings of a field evaluation study of a two-layer highway drainage system (Figure 2.4). The experimental section consisted of a flexible pavement over a two-layer drainage blanket. The drainage blanket consisted of an asphalt treated permeable material over a well graded aggregate layer. The performance of this two-layer system was compared to a control section which had

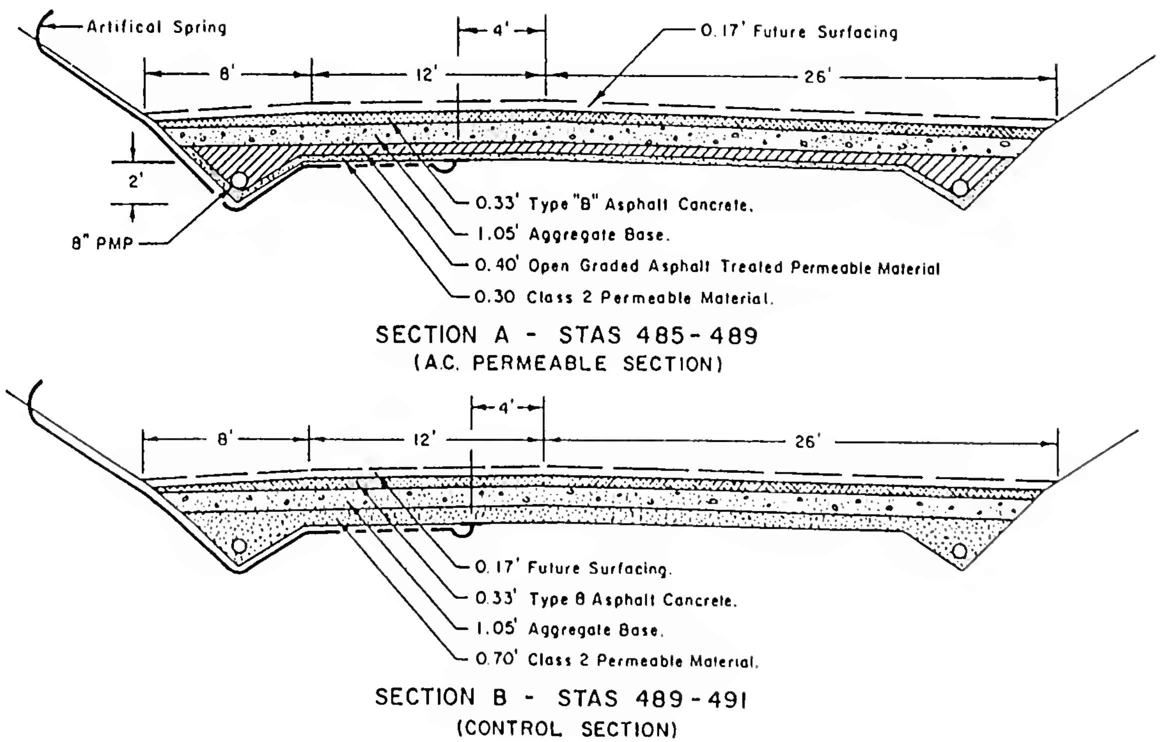


Figure 2.4 Experimental and control sections for two-layer drainage system study (Smith et al., 1970)

a flexible pavement over a layer of permeable base course material. Field permeability tests from the study (Table 2.2) indicated that the drainage capacity of the two-layer system to be three to nine times that of the standard underdrain section, though both sections effectively drained all subsurface water at the site.

Kozlov et al. (1983) investigated drainage conditions and frost action due to surface water underneath concrete pavements. Different gradations of base course materials were tested in the laboratory to identify optimal materials for pavement drainage layers. Two types of drainage layer materials, a bituminous stabilized open graded material (BSOG) and a non-stabilized open graded material (NSOG) were developed. Gradation specifications for both materials are shown in Table 2.3.

Highlands and Hoffman (1987) described a project undertaken by the Pennsylvania Department of Transportation (PennDOT) in which five sections of base/subbase materials representing a range of permeability conditions were constructed (Table 2.4). Test results indicated that open-graded subbases have higher permeabilities as compared to dense graded subbases. Based on the results of the study, Penn DOT changed its specifications to require an open-graded subbase (Figure 2.5) as an interlayer between rigid pavements

Table 2.2 Field permeability test data for two-layer drainage system study (Smith et al., 1970)

Station	Permeability (gal/min) at 43-in. Constant Head			Remarks
	Asph. Perm.	Two-Layer	Control	
485 + 65	—	7.20		
486 + 90	33.00	7.80		
487 + 90	31.80	16.20		Incomplete excavation through asph. perm.
488 + 50	—	4.80		4 ft from artificial spring
489 + 40			1.02[a]	
489 + 85			0.90[a]	
490 + 50			6.60	4 ft from artificial spring—probably piping
Average	32.40	9.00	2.84[a]	

[a]Average of low values 0.96.

Table 2.3 Selected BSOG and NSOG gradation range for New Jersey concrete pavements (Kozlov et al., 1983)

Sieve Size	% Passing (by weight)			
	NSOG		BSOG	
	Max.	Min.	Max.	Min.
1-1/2"	100	100	-	-
1"	100	95	100	100
3/4"	-	-	100	95
1/2"	80	60	100	85
3/8"	-	-	90	60
#4	55	40	25	15
#8	25	5	10	2
#16	8	0	5	2
#50	5	0	-	-
#200	-	-	Add 2% (by weight) mineral filler	

Table 2.4 Subbase material properties for Pennsylvania drainage study (Highlands and Hoffman, 1987)

Subbase Type	Laboratory Permeability K (cm/s)	Field Permeabilities K1 (cm/s)	Field Permeabilities K2 (cm/s)	Lab. $\gamma_{d\,max.}$ (pcf)	Field $\gamma_{d\,max.}$ (pcf)	Lab. $n_{min.}$ (%)	Field $n_{min.}$ (%)	Field e
Aggregate Cement	1×10^{-7} (1)	(7)	(7)	130.1	138.1 (4)	16	16 (4)	0.19 (4)
ATPM	2.3×10^{0} (2)	1.90	2.14	112.7	106.9	31	33	0.51
2B Aggregate	7.6×10^{0} (2)	2.73	8.44	102.9	93.2 (5)	37	43 (5)	0.75 (5)
H.P.	6.4×10^{0} (2)	6.10	6.28	110.0	100.0	32	39	0.63
2A Aggregate	1.8×10^{-4} (3)	0.014 (6)	0.0063 (6)	124.9	125.4	23	23	0.30

(1) Triaxial test permeability
(2) Fabricated falling head test
(3) Standard constant head permeameter
(4) Data obtained from mix design testing
(5) Data derived from field concrete design data
(6) Due to limitations of test equipment, field permeability measurements in 2A Aggregate may not be accurate
(7) No measurements because permeabilities were below the lower testing capabilities of the testing equipment

K = Permeability
K1 & K2 = Permeabilities in orthogonal (90 degrees apart) directions
γ_d = Dry density
n = porosity
e = void ratio

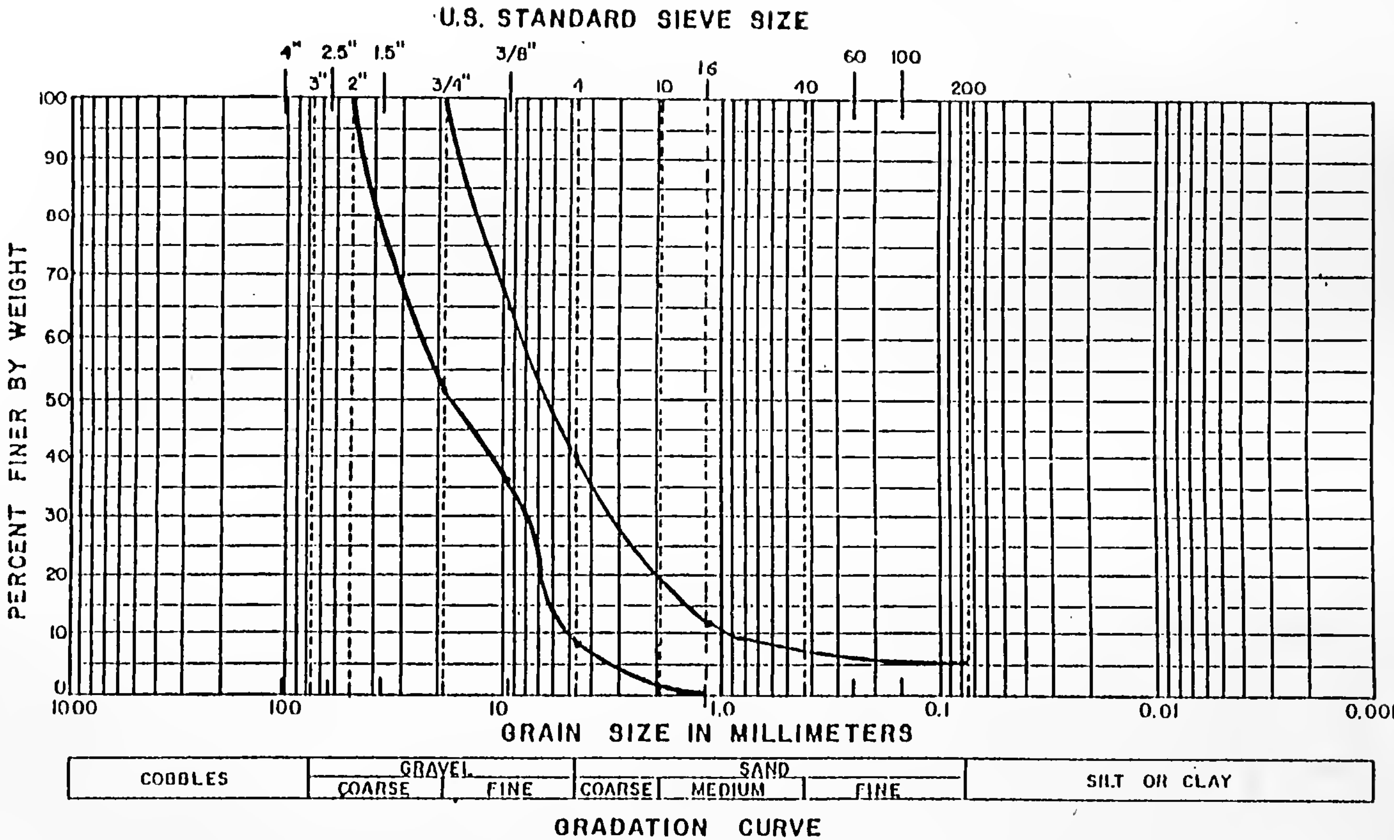


Figure 2.5 Pennsylvania open graded subbase gradation curve (Highlands and Hoffman, 1987)

and dense graded aggregate subbases. Raad (1982) investigated the significance of permeability, compressibility, loading conditions and drainage efficiency on pumping of base course materials. He found that pore pressure increases as the base course permeability decreases. Also, he found the base course compressibility increases. Crovetti and Dempsey (1991) investigated the permeability of the standard Illinois base course materials. Two of these standard materials have permeabilities in excess of 5000 fpd. They recommended the use of Portland cement or asphalt as stabilizing agents if the materials were to be trafficked prior to final paving.

Hajek et.al (1992) in a field study of five paving projects incorporating asphalt treated and untreated open graded drainage layers (OGDLs) conclude that the existence of OGDLs alone does not guarantee better pavement performance. The OGDLs should also be combined in a total internal drainage design consisting of a permeable base and collection system.

The studies listed above underscore the fact that the use of an open graded material in combination with a subdrainage collection system is effective in increasing pavement service life. INDOT has recently developed standards for aggregate subbases, which require the use of open graded granular or stabilized layers in both asphalt and concrete pavements (INDOT, 1992). This will lead to an increase in the cost effectiveness of the highway network and to less frequent

maintenance and rehabilitation for highways in the state.

Pavement-Shoulder Joints

Improperly sealed or unsealed pavement-shoulder cracks and joints are entry points for moisture into a pavement. If a drainage system is not provided, the result will be premature deterioration of the pavement.

Research conducted on German motorways (Sulten, 1983) revealed that water penetrates through joints and stagnate at the slab-subbase interface resulting in disintegration of the bond between the slab and the hydraulically bound subbase. Barksdale and Hicks (1977) stated that it is possible for as much as 70 to 97 percent of rainfall to enter open joints with openings of 0.035 to 0.125 inch, when dry conditions existed beneath pavements. They indicated that deterioration of shoulders in the vicinity of the longitudinal joint was considerably more severe, when a significant quantity of water existed beneath the pavement and the shoulder.

Ring (1977) found that water entering through joints and cracks of concrete pavements is trapped causing high hydrostatic pressure. As a result, there is a loss of subgrade support and faulting due to redistribution of subbase materials. Guinnee and Thomas (1955) stated that the amount of water entering pavements at the edges is greater than that from any other source. Observations by Ridgeway (1976) indicated infiltration rates of up to 0.08 ft^3/hr/ft of crack through joints and cracks in concrete pavements. Figure 2.6

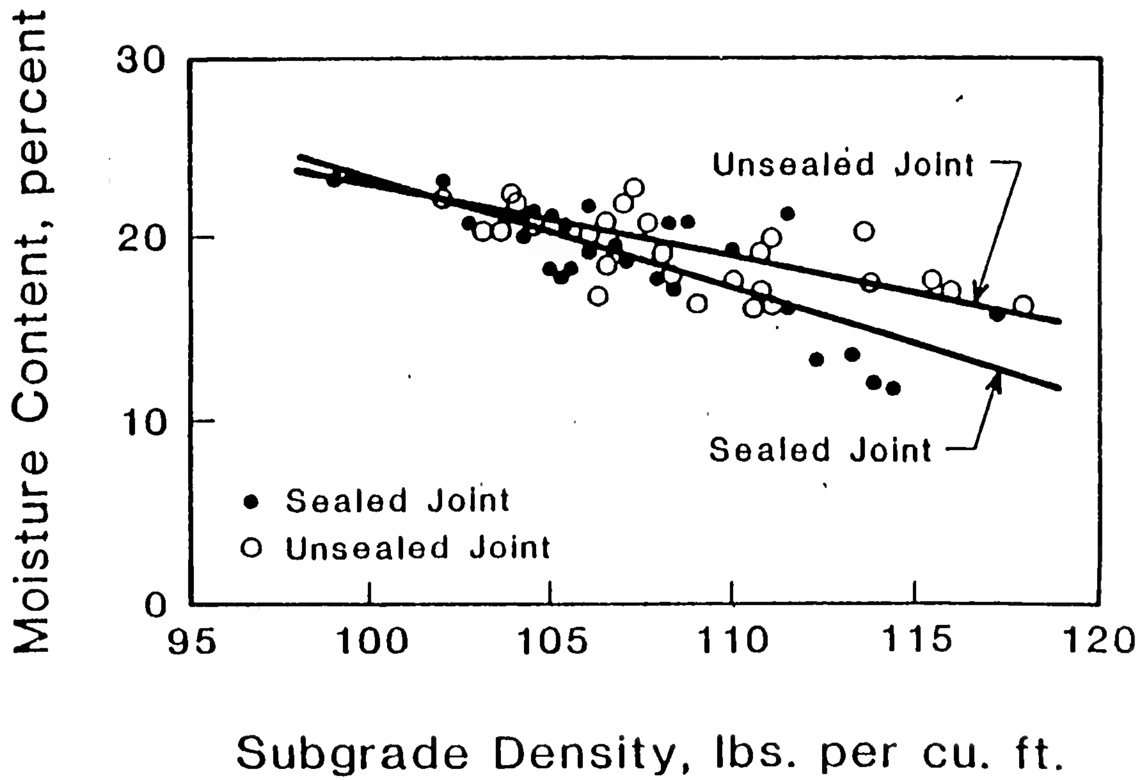


Figure 2.6 Effect of joint sealing on moisture content variation (Dierstein and Mckenzie, 1974)

shows a survey of lane-shoulder joints in Illinois (Dierstein and McKenzie, 1974) where moisture content was found to be higher under longitudinal unsealed lane-shoulder joints than sealed joints. This higher pressure was associated with premature failure of pavements. Dempsey and Robnett (1979) in a study of test sections in Georgia and Illinois found edge joint sealing of pavements reduced outflow by 11.6 percent in jointed concrete pavements and by 16.4 percent in continuously reinforced concrete pavements. Carpenter et al. (1987) stated that there is no consensus around the United States as to what constitutes an adequate lane/shoulder joint seal. The practice is performance dependent and varies from one area to another.

Collector System Components

A pavement subdrainage collector system collects water from the pavement drainage layers and conveys it outside the roadway limits through outlets. It consists of a perforated drainage pipe placed inside a trench with a filter envelope surrounding the pipe. Figure 2.7 shows a typical cross section of a drainage trench. The composition of the pipe and the envelope material play an important role in the efficiency of the subdrainage system.

Clay and concrete tiles and pipes were used in earlier drainage systems. These type of pipes have now been replaced with perforated corrugated metal or plastic pipes. The plastic pipes are flexible conduits and if improperly placed, they

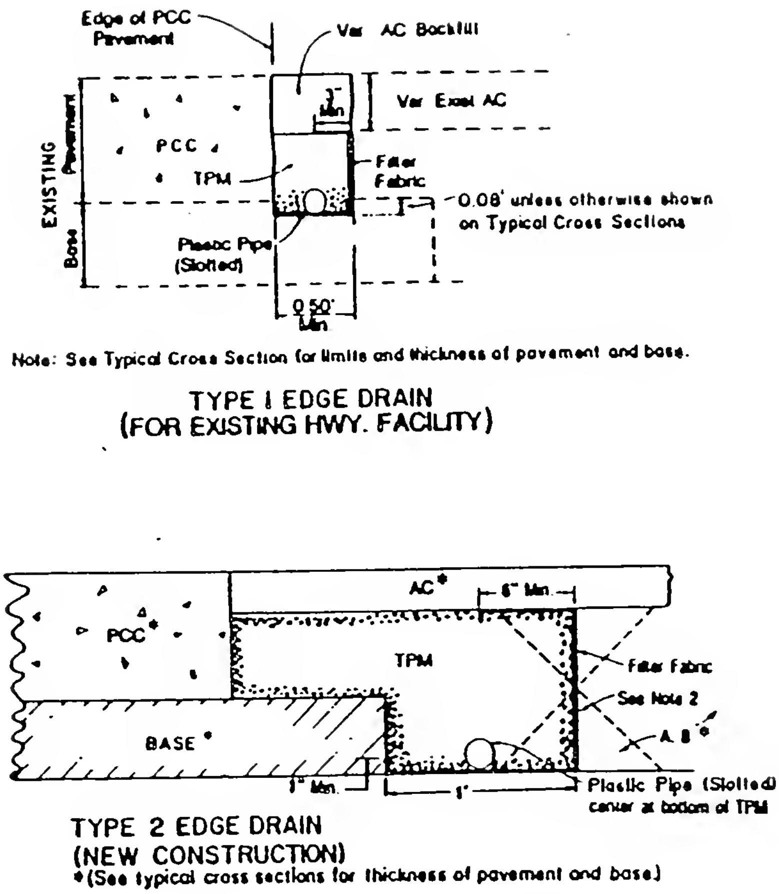


Figure 2.7 Typical cross sections of underdrain trench (Wells, 1985)

deflect excessively. NCHRP Project 4-11 (1980) discusses standards for evaluating plain and corrugated plastic pipes. Also, various state DOTs have their own specifications for the use of different materials for pipes.

The introduction of prefabricated edge drains (PFEDs) or fin drains, consisting of an inner polymer structural core around which a geotextile membrane is wrapped, has been an important development for both new and retrofitted pavement systems. Figure 2.8 shows some designs of fin drains used in highway subdrainage systems (Frobel, 1991). Proponents of prefabricated edge drains have listed ease of placement and relatively low cost as the major advantages over conventional pipe edge drains.

Koerner and Hwu (1991) presented a rational design procedure which can be used for a variety of fin drain products. Dempsey (1988) conducted a study to determine the core flow-capacity requirements of prefabricated edge drains. Six different fin drain materials were tested in a laboratory channel and their core flow capacities compared with conventional pipe edge drain systems. Results from the study indicate that flow zone capacities in excess of 200 gal/hr are required for fin drains to compare with standard pipe edge drain systems.

Studies have been conducted to evaluate and compare the effectiveness of pipe and prefabricated edge drain systems (Hinshaw, 1988; Allen and Fleckenstein, 1988; Highlands et

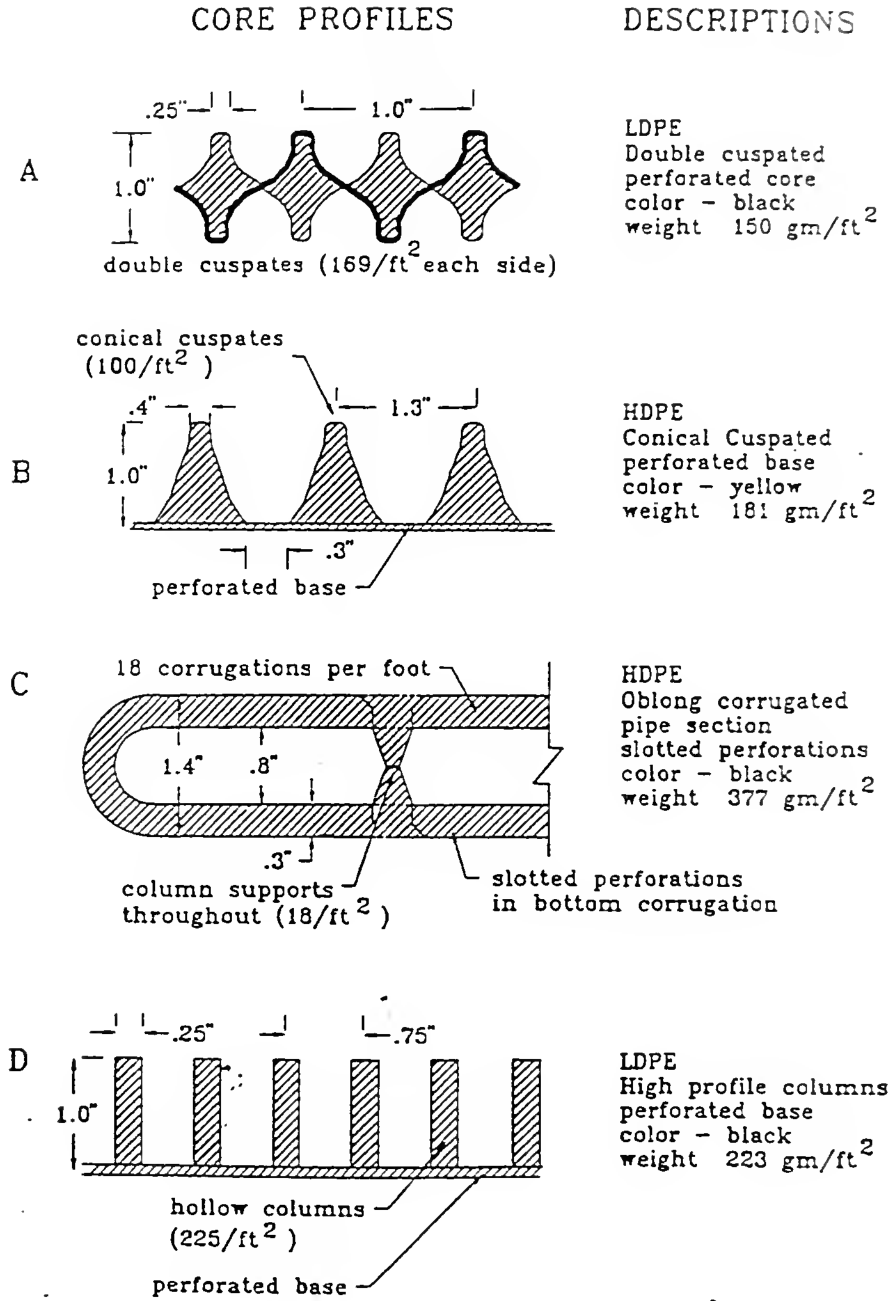


Figure 2.8 Core structural profiles for prefabricated edge drains (Frobel, 1991)

al., 1991). The general conclusion is that performance problems exist with both systems. It is also difficult to isolate the effect of a subdrainage collector system from the overall pavement system performance.

The second component of a drainage trench is the envelope material. The primary reasons for placing envelope materials around edge drains as listed by Dempsey et al. (1971) are as follows:

1. to prevent the migration of soil particles into drains to prevent clogging the drain.
2. to provide a material in the immediate vicinity of drain openings which is more permeable than the surrounding soil.
3. to provide a suitable bedding for drains.
4. to stabilize the soil on which drains are being laid.

Cedegren and O'Brien (1971) and Moulton (1980) have recommended the following design criteria for drainage envelope materials for proper functioning:

$$(D_{15}) \text{ backfill} \leq 5 \ (D_{85}) \text{ protected soil} \qquad (2\text{-}1)$$

$$(D_{50}) \text{ backfill} \leq 25 \ (D_{50}) \text{ protected soil} \qquad (2\text{-}2)$$

$$(D_{85}) \text{ backfill} > 1.2 \text{ (slot width of pipe)} \qquad (2\text{-}3)$$

$$(D_{85}) \text{ backfill} > 1.0 \text{ (hole diameter of pipe)} \qquad (2\text{-}4)$$

$$\text{trench width} \geq q_d / 2 \ (k_t) \qquad (2\text{-}5)$$

where: D_x = the particle size for which x percent of the material will be smaller

q_d = design drainage rate

k_t = permeability of backfill material

The protected soils specified in the above equations are the base/subbase and subgrade, as water from these layers are expected to flow into the trench. Three placement locations of the trenches have been practiced;

1) at the pavement edge, which is more common for fin drains,
2) under the shoulder at some distance from the pavement edge which is more common for pipe edge drains,
3) at the shoulder outer edge.

Procedures for analysis and design of pipes and prefabricated edge drains have been given by Cedergren (1974), Moulton (1980) and Carpenter (1990).

Drainage Design Criteria

Design and performance of drainage layers and collector systems are not exercises in isolation. Rather, they are tied to an overall approach of draining water from various sources (Figure 2.9) out of the pavement system. To this end, two basic design philosophies are practiced (Ridgeway, 1982).

a) Time required for a certain percentage of drainage of a saturated base or subbase should not exceed a certain value.
b) An inflow-outflow criteria where the outflow rate is greater than or equal to the inflow rate.

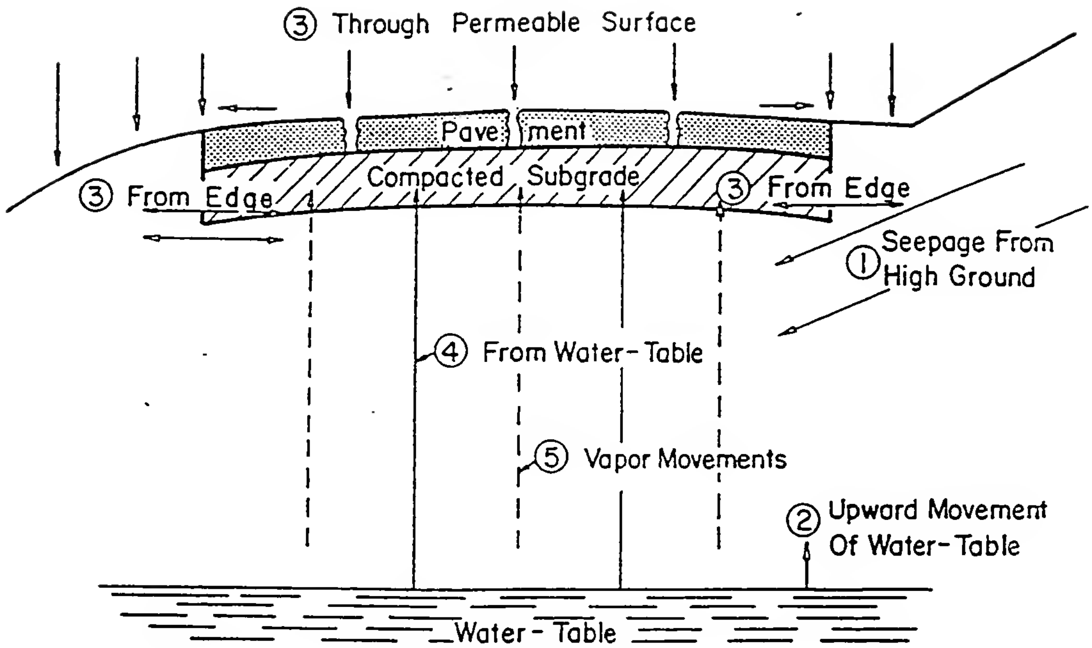


Figure 2.9 Sources of moisture in pavement systems (Low and Lovell, 1959)

To meet the first criteria, Casagrande and Shannon (1951) and Barksdale and Hicks (1977) have given procedures for estimating the time required to remove 50 percent of the drainable water from the pavement system. The Corps of Engineers (1946) recommend a time of 10 days for airport pavements, whereas Barksdale and Hicks (1977) suggest a time of 2 to 6 hours for highway pavements. Darter and Carpenter (1987) have proposed a time of 5 hours as acceptable to reach an 85 percent saturation level (Figure 2.10). AASHTO Design Guide (1986) lists the times corresponding to different levels of drainage for improved performance (Table 2.5).

For the second criteria, there are two approaches to estimate infiltration of water through a pavement surface.

a) The first approach by Cedergren et al. (1972) is based on the intensity of precipitation. A 1 hour/1 year frequency precipitation is multiplied by a coefficient to achieve a design infiltration rate. Suggested coefficients range from 0.33 to 0.5 for bituminous pavements and from 0.5 to 0.67 for concrete pavements.

b) The second approach by Ridgeway (1976) is based on the duration of precipitation and the estimate of the water carrying capacity of a pavement crack or joint. For design purposes, an infiltration rate of 0.1 $ft^3/hr/ft$ of crack is recommended.

Moulton (1980) has summarized the recommended design criteria for drainage systems into the following five steps:

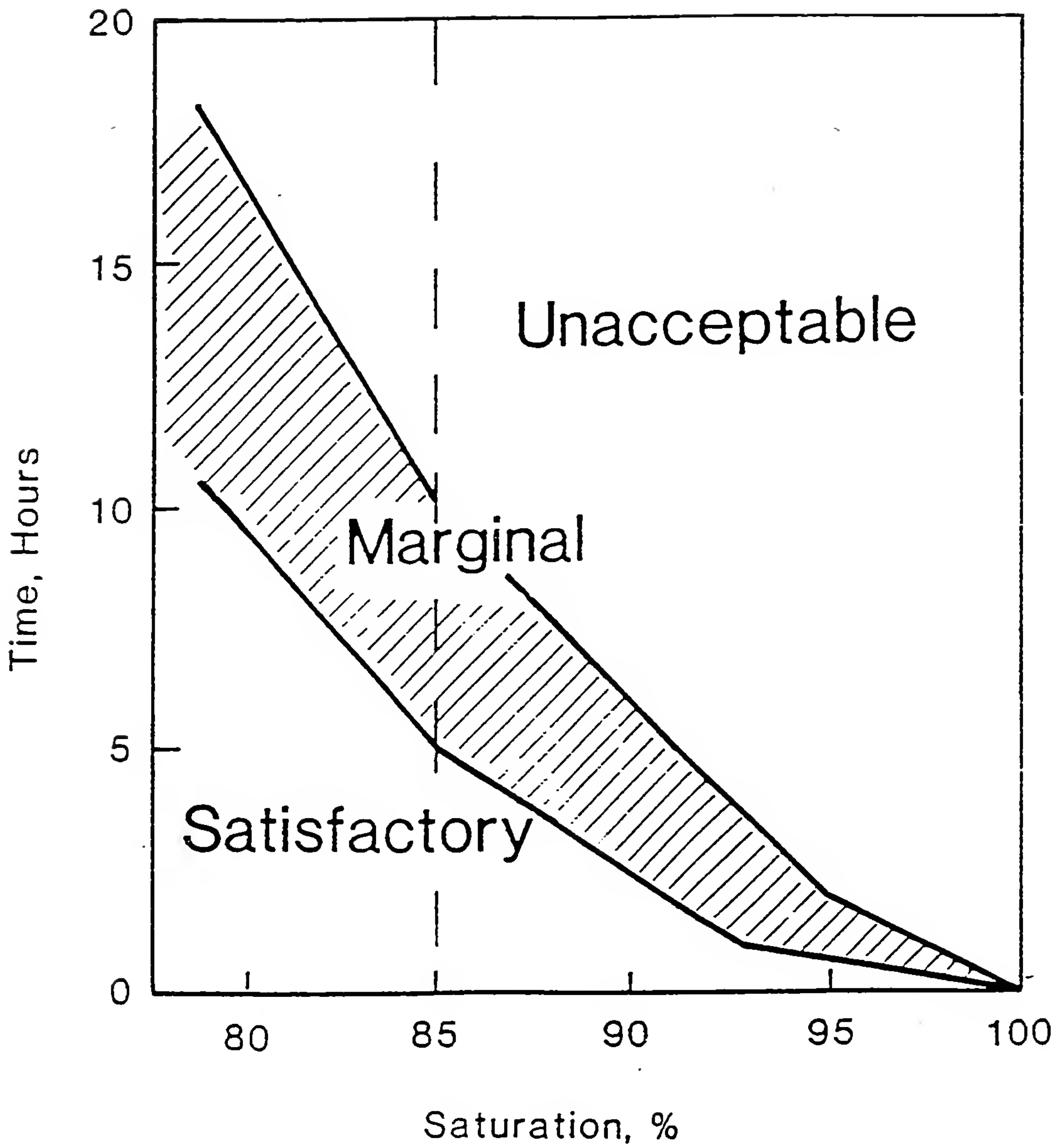


Figure 2.10 Drainage criteria for granular layers (Darter and Carpenter, 1987)

Table 2.5 Quality of drainage for pavement sections (AASHTO, 1986)

Quality of Drainage	Water Removed Within
Excellent	2 hours
Good	1 day
Fair	1 week
Poor	1 month
Very Poor	Will not drain

1. Assemble all available data on highway and subsurface geometry, soil and material properties, and factors contributing to the quantity of moisture in pavements.
2. Determine the quantity of water that must be removed by the pavement drainage system.
3. Design the pavement drainage layers for rapid removal of the net inflow.
4. Design the collector system for removal of water from the drainage system.
5. Conduct a critical evaluation of the design with respect to expected long term performance, maintenance and cost.

Environmental Effects on Subdrainage

Climate, geologic location and other environmental factors have considerable influence on pavement performance. Precipitation and temperature control soil moisture conditions and influence the type and thickness of pavements required for roads and airfields.

A number of researchers have discussed the effects of these variables on moisture conditions in pavement systems (Eno, 1930; Coleman and Russam, 1961; Fang, 1969). In the words of Eno (1930),

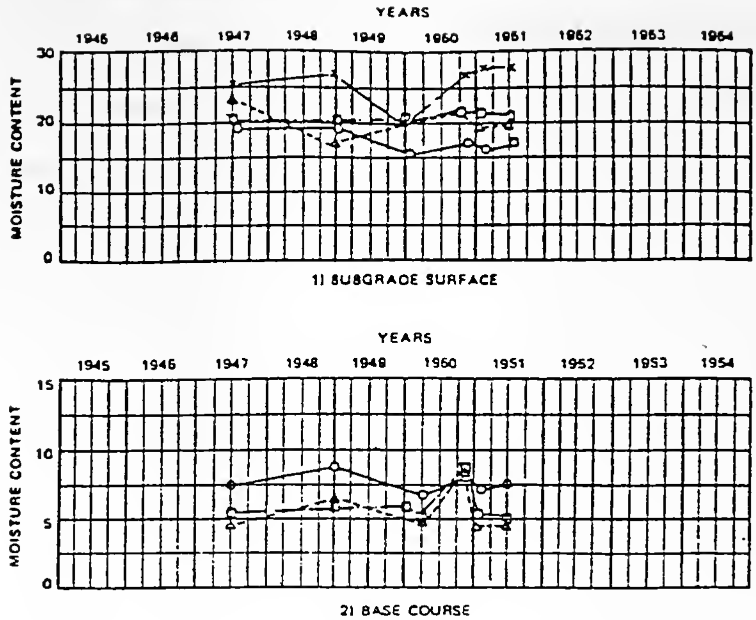
> "One of the very important, if not the most important phases of climate relative to its effects upon the highway is the amount, distribution, intensity, character, and disposition of precipitation".

A field study conducted by the Corps of Engineers (1955) at different airfield pavements shows the influence of high

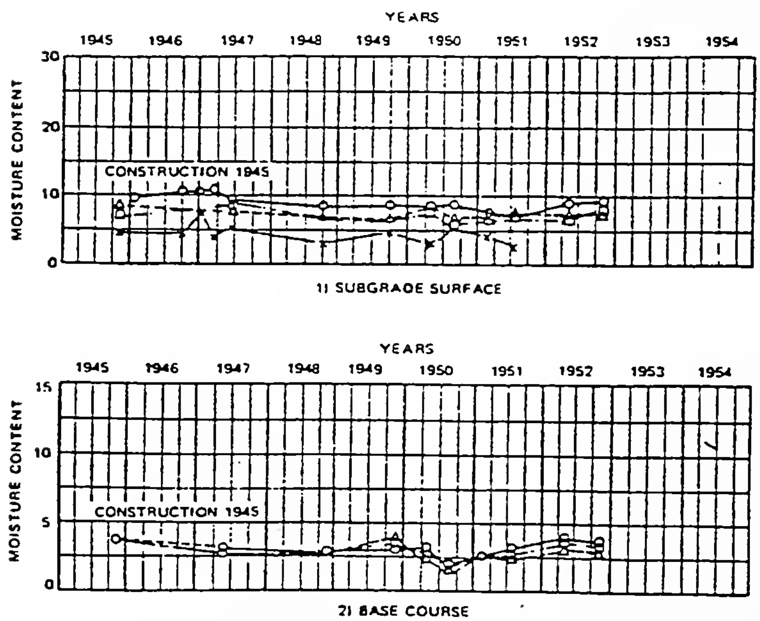
precipitation on the moisture content of base and subgrade materials (Figure 2.11). Investigations by Marks and Haliburton (1969) indicated precipitation has a major effect on moisture variation in pavements with poor condition ratings. Stevens et.al (1949) stated that high precipitation during the fall season tended to saturate the subgrade and base and was related to the spring pavement breakup in Virginia.

Groundwater conditions may contribute to accumulation of moisture in a pavement system. A high groundwater table can allow both capillary water or water in vapor form to migrate towards the surface. Turner and Jumikis (1956) in a study of six New Jersey soils showed that precipitation could change the water table level and correspondingly the subgrade moisture content. Melting snow was more significant than rain. Chu et al. (1972) found a positive correlation between subgrade moisture content and high groundwater table for pavement systems in South Carolina (Figure 2.12).

The severity of the problem of moisture increases in areas where frost penetration or freeze-thaw cycles occur. Freezing temperatures during winter months result in the formation of ice crystals from the various sources of water which infiltrate and get trapped in the pavement layers. During spring-thaw periods, water from the melting crystals contribute to moisture content increase, which in turn results in early deterioration of the pavement. In a study of AASHO



a) Memphis Municipal Airports (35 in. of rainfall/year)



b) Kirtland Air Force Base (15 in. of rainfall/year)

Figure 2.11 Moisture content variation for airfield pavements (Corps of Engineers, 1955)

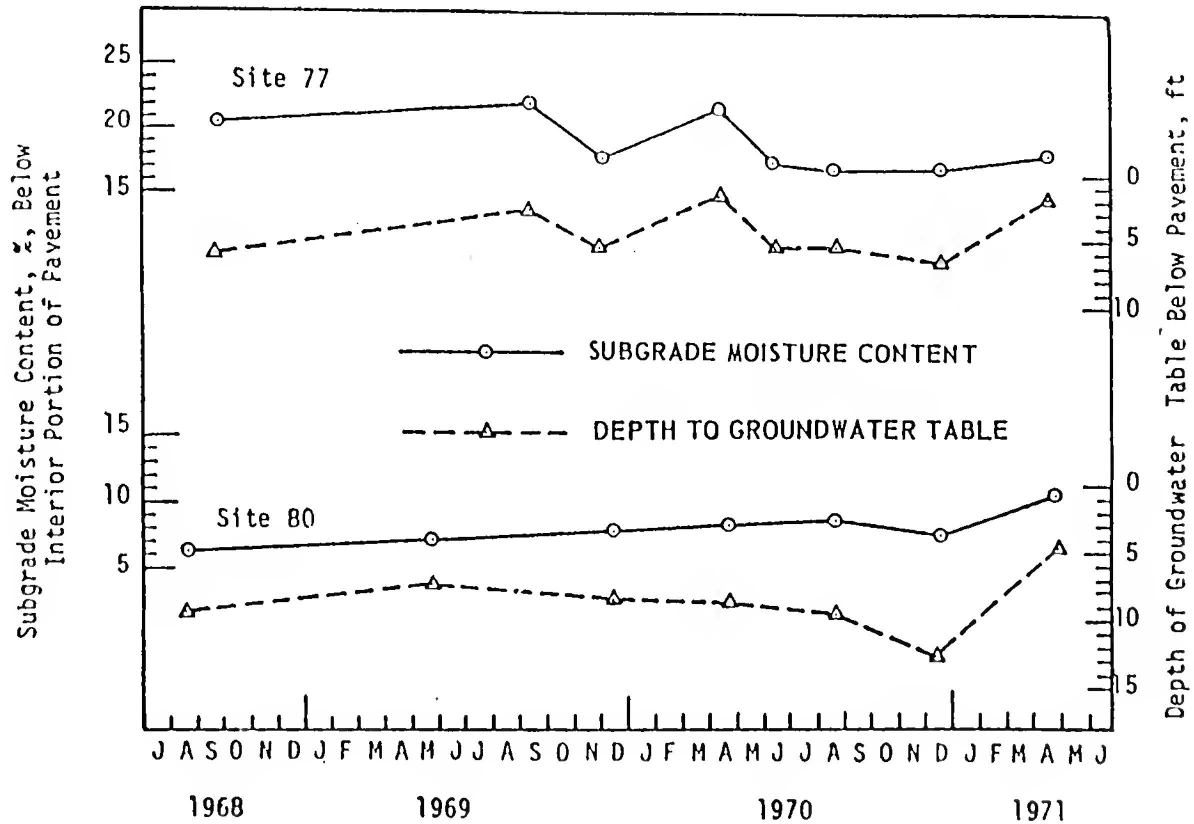


Figure 2.12 Variations in moisture content compared with fluctuations in groundwater table (Chu et al., 1972)

Road Test results on flexible pavements, Benkelman (1962) found the detrimental effects of ground freezing and moisture to be the greatest during spring months.

There are several reports which describe the effects of temperature and frost on pavement performance (Johnson, 1952; Johnson and Lovell, 1953; Low and Lovell, 1959; OECD, 1974). The US Army Corps of Engineers (1959) has criteria and procedures for the design and construction of pavements for frost conditions. Moulton and Schaub (1969) developed a rational approach to the design of flexible pavements for resisting the detrimental effects of frost action. More recently, Chisholm and Phang (1983) undertook a 5 year program of measuring and predicting frost penetration in pavement structures across Ontario and developed a computer program capable of predicting the depth and time pattern of frost penetration beneath pavement structures.

Experiments conducted by the Ontario Ministry of Transportation (McMaster et al., 1982) show that surface water infiltration in frost areas has a detrimental effect on pavement performance. Removal of moisture from pavements through plastic pipe edge drains resulted in reduced heaving and distortion of asphalt pavements.

Moisture Movement Underneath Pavements

Moisture is a fundamental variable in all problems of soil behavior. It has special significance in highway

pavements. Highways are thin structures built on a soil foundation. Also, subbase and base layers are soil materials. These soils or subgrades may be subjected to large variations in moisture contents. Consequently, the control of moisture is of prime importance in pavement design, construction, behavior and performance.

Saturated and Unsaturated Flow

Moisture movement in underlying layers of pavements can be generalized into two systems. Saturated, in which all the voids are filled with water, and unsaturated, in which both air and water are present. The latter is the more common kind of flow in soils, as even in the case of practically saturated flow, one can expect about 2-10% of air voids. Both types of flow are caused by a driving force due to a potential gradient, with flow taking place in the direction of decreasing potential. For the same elevation, it is the gradient of a positive pressure potential for saturated flow, whereas in case of unsaturated flow, it is the negative pressure potential often termed as 'matric potential', 'moisture tension' or simply 'suction'.

Saturated flow is best described by Darcy's Law for flow in porous media, and for a one-dimensional flow may be given as:

$$q = k\ i\ A \qquad (2\text{-}6)$$

where: q = specific discharge rate

k = constant, defined as "hydraulic conductivity"

i = $\partial h/\partial x$ = hydraulic gradient

A = cross-sectional area normal to flow direction

h = piezometric head = $z + u/\gamma_w$

z = elevation of the point of interest

u = water pressure

γ_w = unit weight of water

x = direction of flow

For unsaturated flow, the above equation is extended and expressed as:

$$q = - [k(\theta)] \nabla h \qquad (2\text{-}7)$$

where: q = specific discharge rate

$k(\theta)$ = hydraulic conductivity as a function of unsaturated moisture content

∇ = Laplacian operator

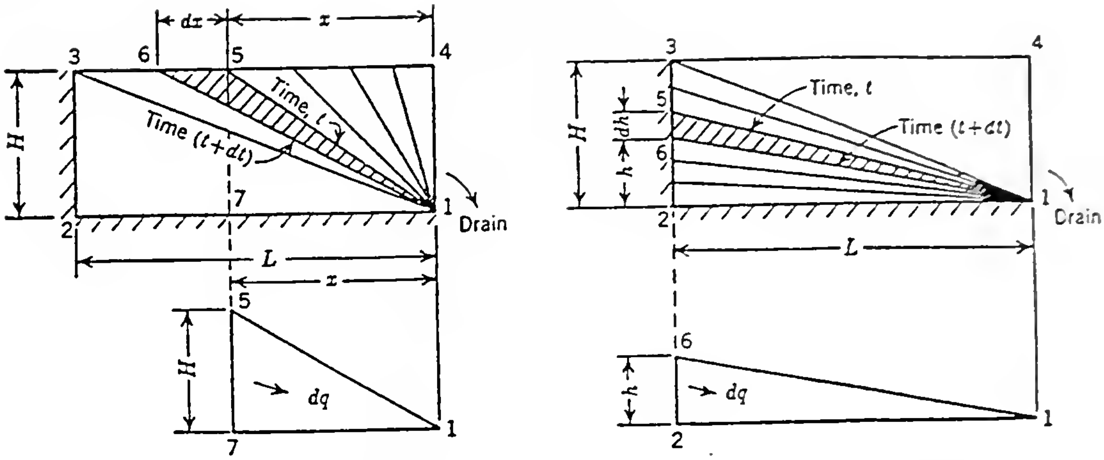
h = piezometric head = $z - \psi$

z = elevation head

ψ = matric potential or suction

Casagrande and Shannon (1951) presented a theoretical analysis of moisture movement through a saturated base course. The model considers both horizontal and sloping bases and a linear free water surface that changes with time (Figure 2.13). They defined the progress of drainage in terms of two dimensionless parameters:

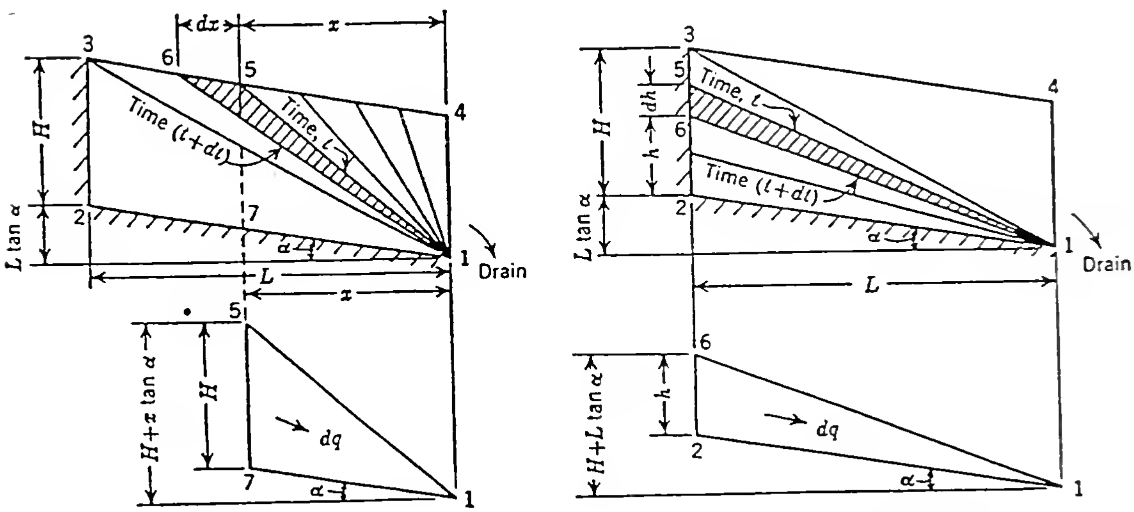
a) Degree of Drainage 'U' defined as the ratio of drained area to total area.



(a) U EQUAL TO OR GREATER THAN 50%

(b) U EQUAL TO OR LESS THAN 50%

Assumed Progress of Free Water Surface—Horizontal Base



(a) U EQUAL TO OR GREATER THAN 50%

(b) U EQUAL TO OR LESS THAN 50%

Assumed Progress of Free Water Surface—Sloping Base

Figure 2.13 Base Drainage Model (Casagrande & Shannon, 1951)

b) Time factor 'T' which depends on the properties of the base material.

Liu et al. (1983) developed a model based on Casagrande and Shannon's work replacing the linear free water surface with a parabolic surface and incorporated other variations which make the model more suitable to field conditions. Cedergren (1989) has used the technique of flow nets for infiltration studies of base courses on impermeable foundations using Darcy's Law.

The main limitations of the methods described above are the assumptions that the base is fully saturated and that water is readily drained out from the system. As soil desaturates, some of the pores become air filled and suction develops, entailing a steep drop in hydraulic conductivity. This may result in very long times for any appreciable flow to occur. Still, the methods are a good first approximation in the design of pavement drainage systems.

Though soil physicists have been dealing with unsaturated moisture movement in soils for quite sometime, Wallace (1975, 1977) was the first to apply the concepts to pavement systems. A one-dimensional infiltration model based on finite difference approximation was introduced to analyze a simple pavement cross-section (Figure 2.14) and study the effectiveness of alternative forms of pavement subdrainage. Moisture movement profiles for various cross section designs were given therein. The seepage model 'PURDRAIN' developed in

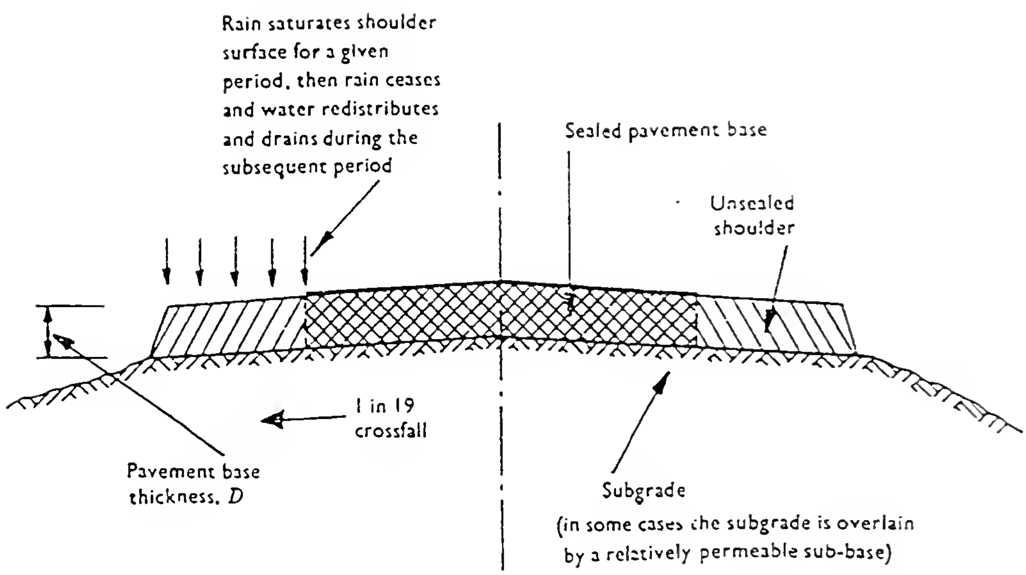


Figure 2.14 Pavement cross section for infiltration analysis (Wallace, 1975)

parallel to the present study (Espinoza et al., 1993) is based on the work performed by Wallace.

The two fundamental relationships affecting moisture movement in unsaturated pavement systems are a) hydraulic conductivity-moisture content and b) suction-moisture content. This is due to the fact that hydraulic conductivity does not remain constant, but decreases as the degree of saturation decreases, or as suction increases as shown in Figure 2.15.

A moisture content-suction relationship can be defined by a characteristic curve as shown in Figure 2.16. The hysteretical nature of the relationship between moisture content and matric suction shows that the process of wetting-up and drying depends on the initial conditions and moisture content at a given point. The relationships between hydraulic conductivity, moisture content and suction are not unique. It is therefore necessary to obtain values of these parameters in forming relationships for different types of base/subbase materials and subgrade soils.

Measurement of Hydraulic Conductivity

Various field, laboratory and analytical methods exist for evaluating saturated and unsaturated hydraulic conductivities (Bouwer and Jackson, 1974; Klute and Dirksen, 1986; Cedergren, 1989b). Table 2.6 summarizes these methods. Moulton and Seals (1979) developed a prototype field device for measuring in-situ horizontal permeability of saturated

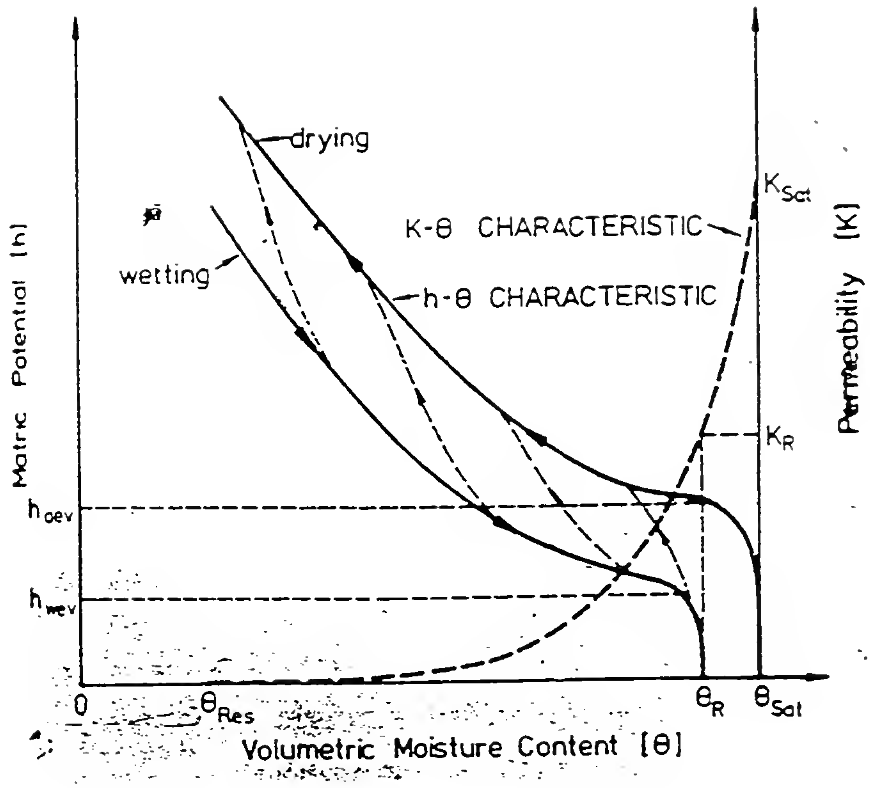


Figure 2.15 Soil moisture characteristics (Wallace, 1977)

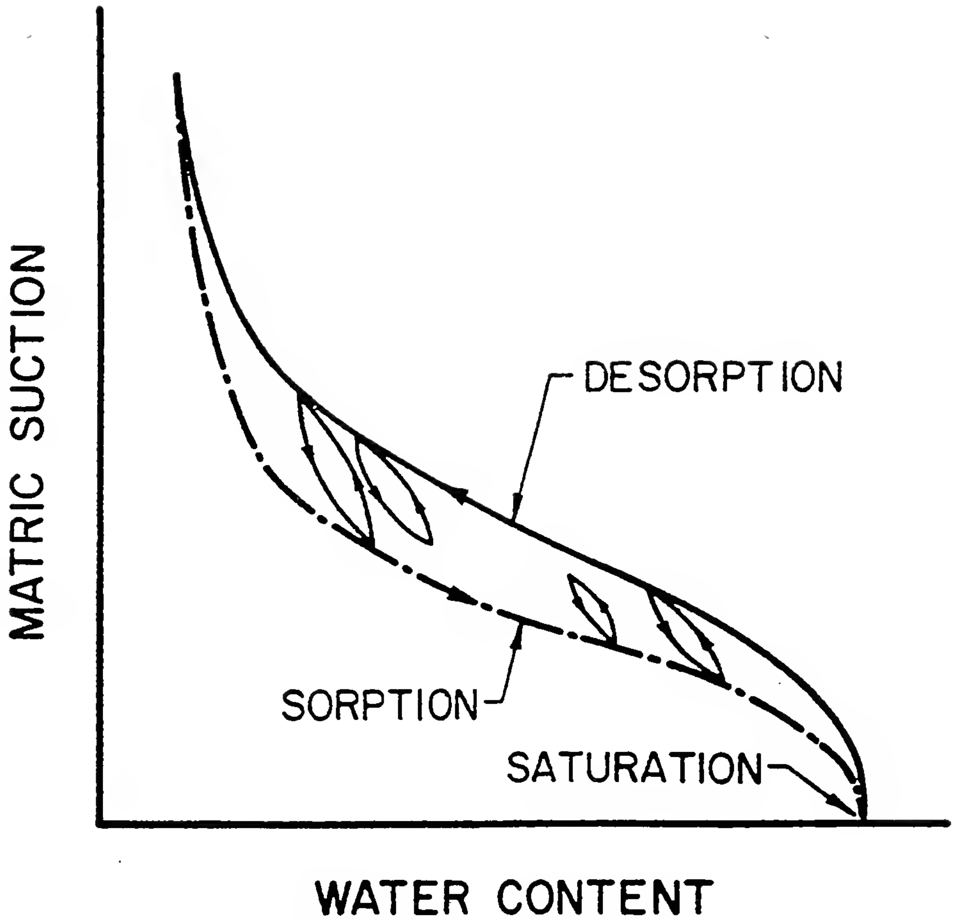


Figure 2.16 Hysteresis effects of drying and wetting on matric suction (Janssen and Dempsey, 1980)

Table 2.6 Methods of measuring hydraulic conductivity (Bouwer and Jackson, 1974)

Saturated Hydraulic Conductivity		Unsaturated Hydraulic Conductivity
Below Water Table	Above Water Table	
Auger Hole Method	Shallow well Pump-in Method	Two-Plate Method
Tube Method	Cylinder Permeameter Method	Long Column Method
Piezometer Method	Infiltration Gradient Technique	Advance of Wetting Front Method
Well Point Technique	Air-Entry Permeameter Technique	Pressure Plate Outflow Method
Two-well Technique	Double-Tube Method	Instantaneous Profile Method
Four-well Technique		Entrapped Air Method
Multiple-well Technique		Calculation of Conductivity from water characteristics a. Model of Marshall b. Model of Brooks & Corey
		Computer Techniques
		Field Techniques

base and subbase courses. A number of charts and nomographs have been developed to estimate permeability based on material properties. Two of the most frequently used in drainage design were developed by Cedergren (1974) (Figure 2.17) and by Moulton (1980) (Figure 2.18).

Elzeftway and Dempsey (1976) developed a method to predict the unsaturated hydraulic conductivity of pavement subgrade soils. This method utilizes moisture content-matric suction relationship of soils determined in the laboratory using 'Tempe' cells. Figure 2.19 shows a standard 'Tempe' cell. El Tani (1991) developed a permeameter for unsaturated soils by observing the way in which pore water recovers hydrostatic equilibrium. A cylinder containing unsaturated soil is supplied with two pressure transducers which indicate pressure values of pore water at the top and bottom of the sample. The cylinder is turned upside down every time the state of reference (or hydrostatic equilibrium) is reached. Hydraulic conductivity is deduced from curves of which represent pressure as a function of time at the top and bottom of the sample. The permeameter makes it possible to measure the hydraulic conductivity at very low degrees of saturation. A schematic of the permeameter is shown in Figure 2.20.

Measurement of Moisture Content

Moisture content can be expressed either in terms of gravimetric moisture content 'ω' or volumetric moisture

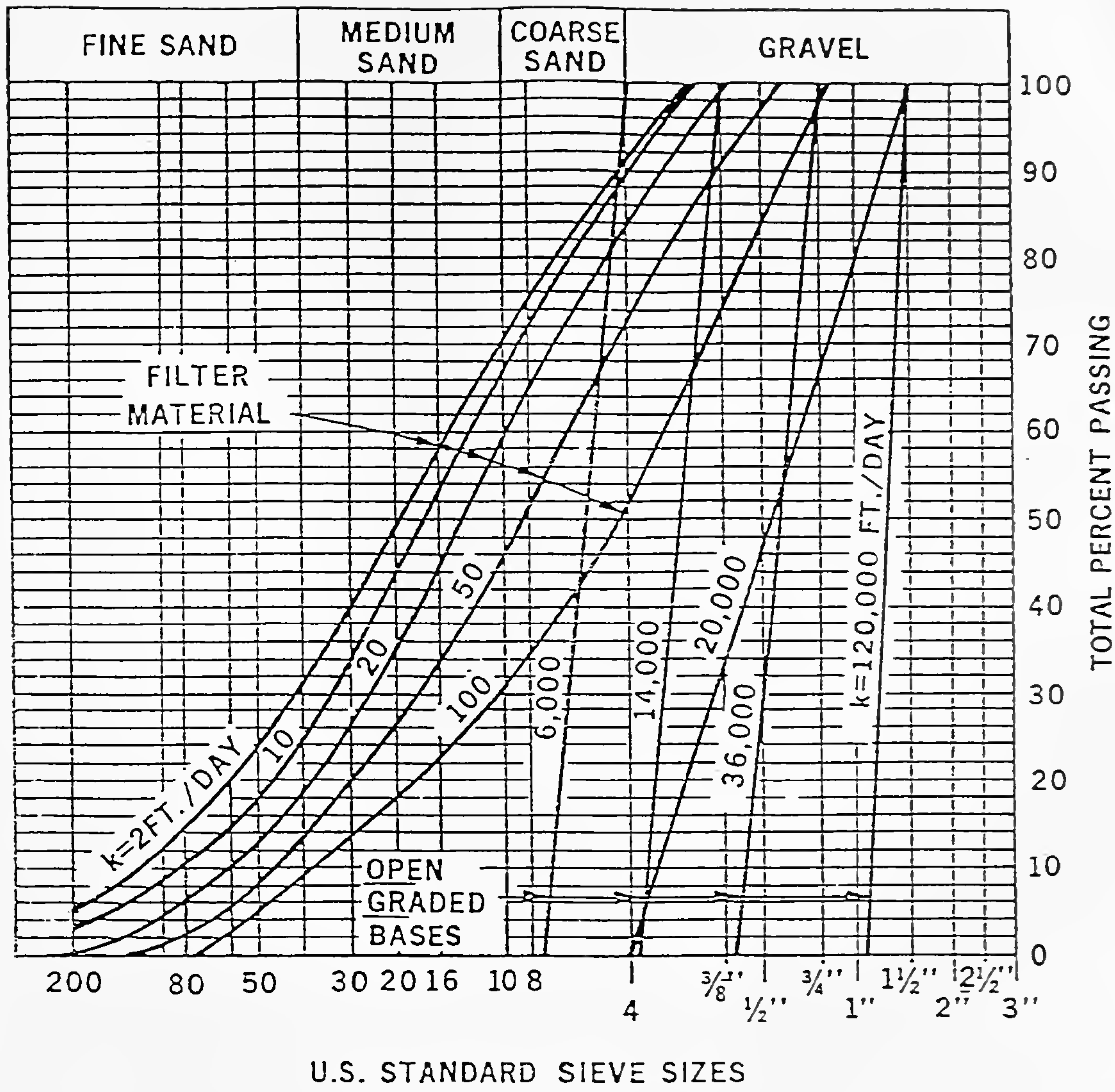


Figure 2.17 Permeability and gradation of base and filter materials (Cedergren, 1974)

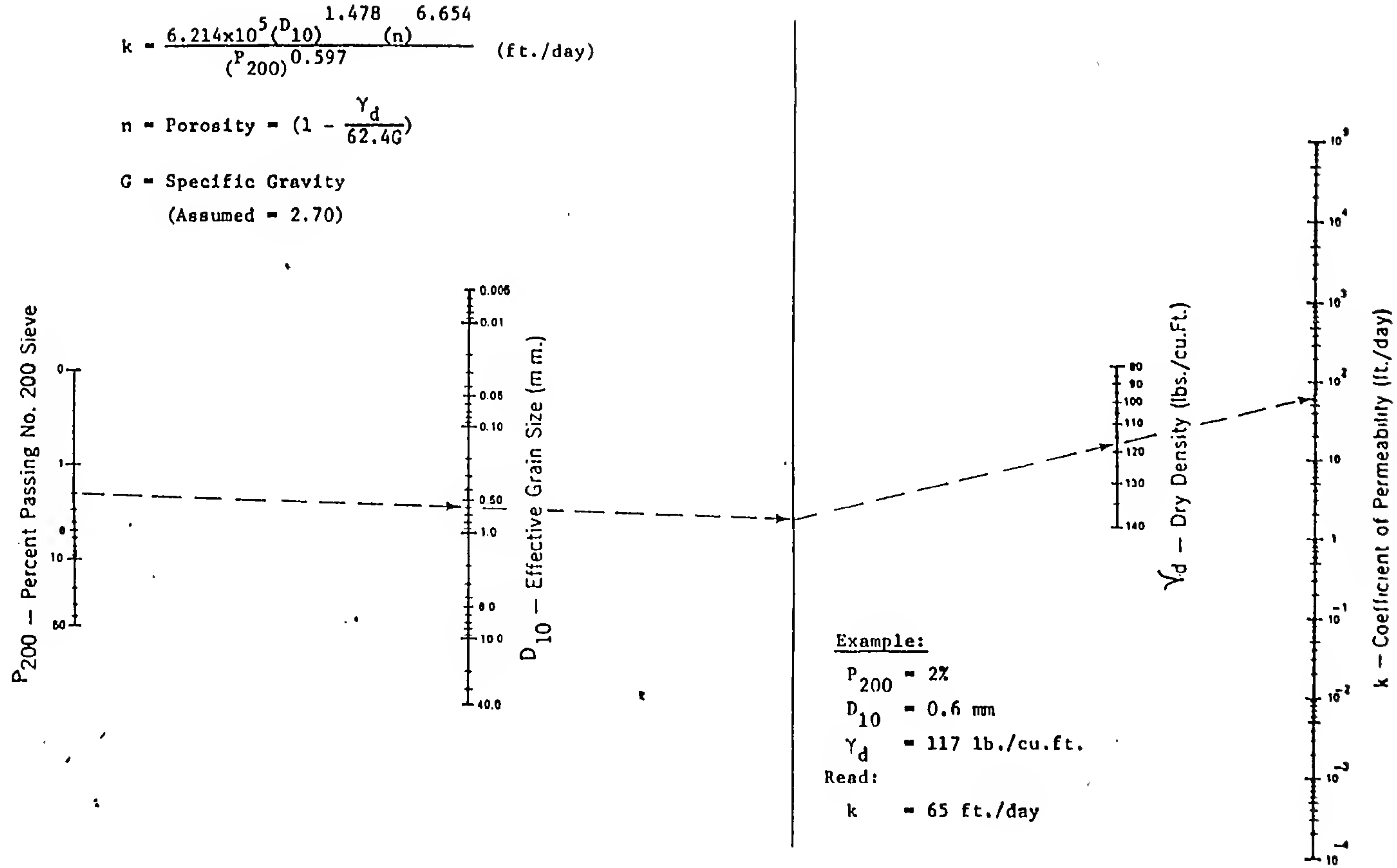


Figure 2.18 Nomograph for estimating co-efficient of permeability of granular materials (Moulton, 1980)

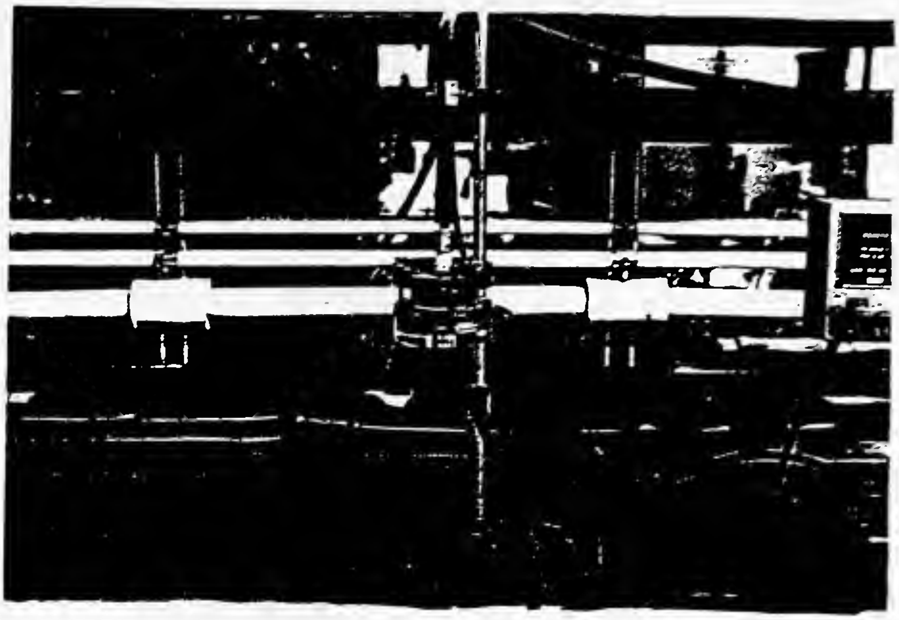


Figure 2.19 View of a standard Tempe cell

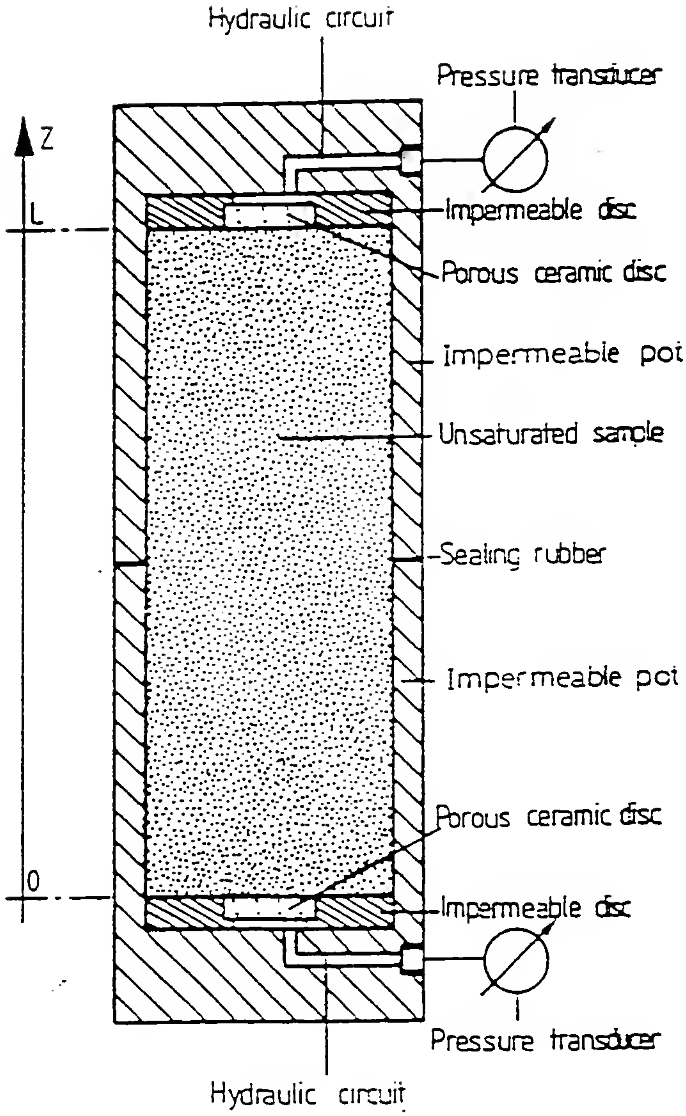


Figure 2.20 A permeameter for measuring unsaturated hydraulic conductivity (El Tani, 1991)

content 'θ'. There are direct and indirect methods of measuring soil moisture content (Gardner, 1965; Curtis and Trudgill, 1975; Hillel, 1982). The direct method called 'gravimetric method' is based on weighing a sample of a moist soil and drying it to a constant weight in an oven. The gravimetric moisture content, then is the ratio of the weight loss on drying to the dry weight of the sample.

Two common methods of measuring moisture content indirectly are through the use of electrical resistance blocks or by neutron moisture probes. The electrical resistance block consists of a gypsum cast around two electrodes. The gypsum block is wetted thoroughly and buried in the soil to ensure good contact between the soil and block. At equilibrium, resistance measurements are made using an ohm meter and converted to water content values using calibration curves.

In the neutron probe method fast neutrons are emitted into the soil through a probe. The fast neutrons collide with hydrogen atoms of water and are scattered. The proportion of neutrons returning to the probe is related to the water content. The probe method is more accurate but the electrical resistance method is more convenient for long term monitoring of soil moisture.

Time-domain reflectometry (TDR) is a relatively new technique being used to monitor soil water content. The technique involves measuring changes in the apparent dielectric permittivity of soil which in turn is related to

volumetric water content. Soil solids have a dielectric constant of 2 to 5 compared to water which has a value of 80. Thus a measure of the dielectric constant of soil is a good measure of its water content. A schematic of the system is shown in Figure 2.21. Topp et al. (1980) used a time-domain reflectometry (TDR) technique to measure the dielectric constant of a wide range of granular soils. They also developed an empirical relationship relating the dielectric constant to the water content of soils.

Measurement of Soil Suction

Suction is a stress property which expresses the attraction that soil has for capillary water. Evaluation of soil suction is as important as determining soil water content. Richards (1949) and Gardner (1965) described various methods of measuring soil suction. Fredlund (1989) presented a state-of-development in soil suction monitoring for roads and airfields.

Tensiometers are the most common and widely used devices for measuring of suction in the field. Such devices are illustrated in Figure 2.22. A tensiometer essentially consists of a fine porous ceramic pot connected by a tube to a manometer or vacuum gage. The porous pot is placed in intimate contact with the soil so that water passes through the pot until equilibrium is achieved between suction on the gage and the soil. To measure suction in a laboratory, use is made of

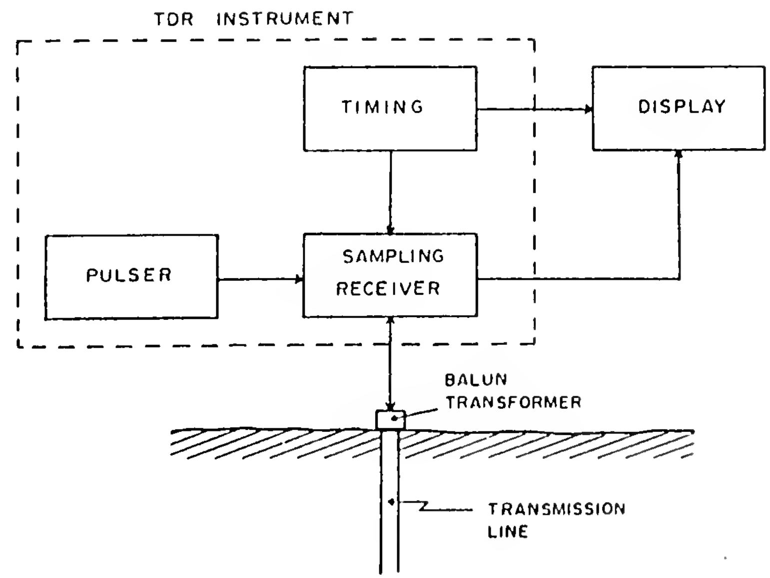


Figure 2.21 Block diagram of Time-Domain Reflectometer (Topp et al., 1980)

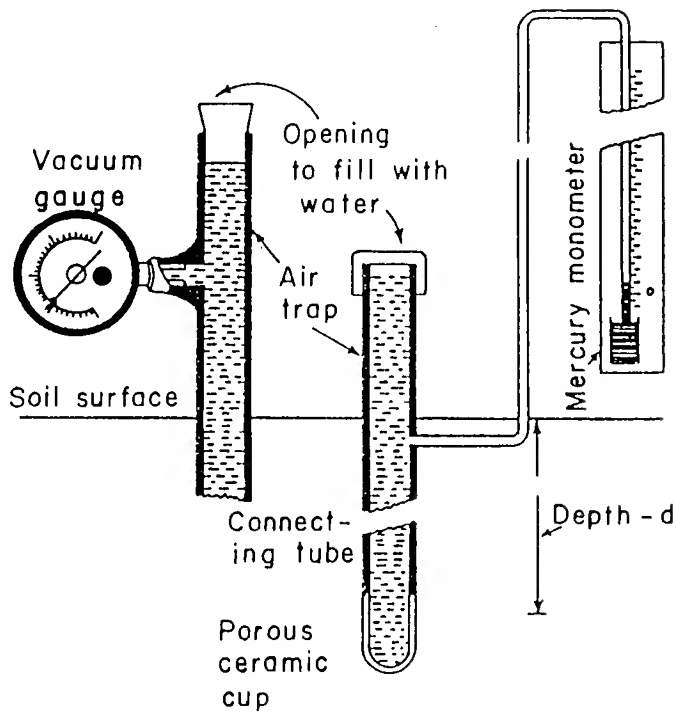


Figure 2.22 Schematic illustration of parts of a tensiometer (Hillel, 1982)

tempe cells for low suction ranges and of a pressure membrane apparatus for high suction ranges. A schematic of the pressure membrane apparatus is shown in Figure 2.23.

Janssen and Dempsey (1980) determined soil-moisture relations of 24 soils in Illinois using the above equipment and discussed the influence of soil type on matric suction and hydraulic conductivity. ASTM (1991) has set standards for measuring moisture-suction relationships for various soils. A detailed procedure is described in Chapter 5.

Chapter Summary

The concept of positive pavement drainage though not new was slow in being accepted and implemented. During recent years, considerable progress has been made in the use of new materials and in the analysis, design and performance of pavement subdrainage systems.

A better understanding of the moisture movement in pavement systems and the hydraulic properties controlling it has been achieved. The use and proper design of new drainage materials for base/subbase courses and edge drains to facilitate flow of moisture out of the pavement system will in the long run benefit the highway system in this country through reduced cost of maintenance and longer service life.

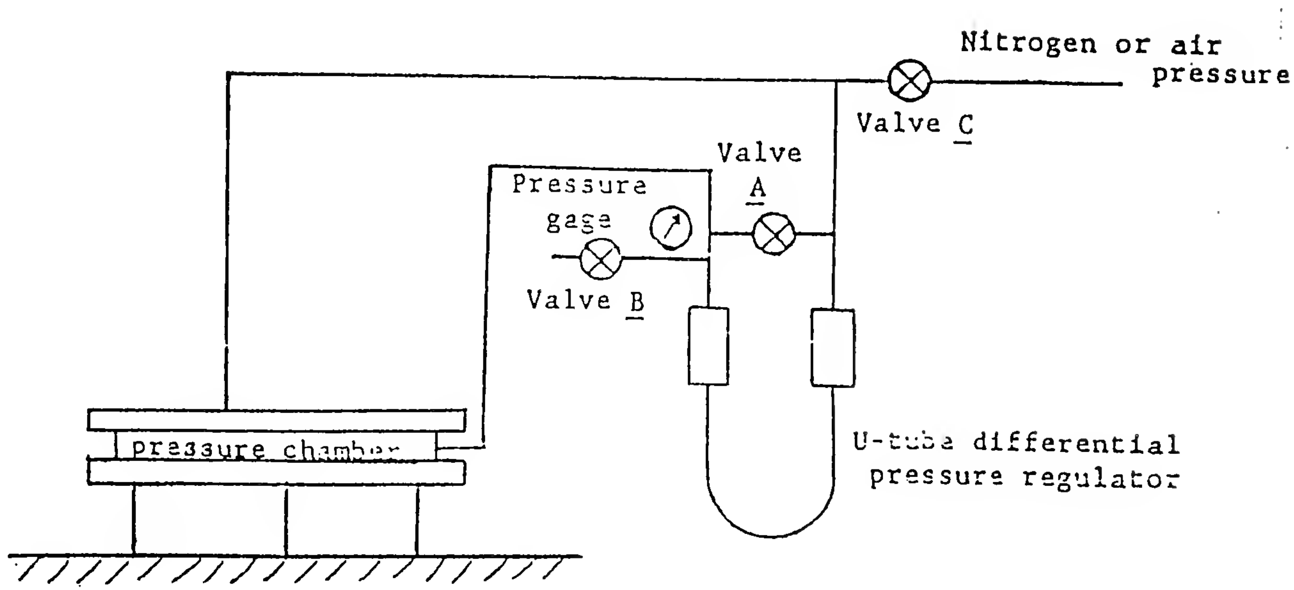


Figure 2.23 Schematic illustration of pressure chamber apparatus (ASTM, 1991)

CHAPTER 3 - COLLECTOR SYSTEM INSPECTION METHODOLOGY

Background

A subdrainage system may be considered to include two basic components, drainable base/subbase layers and a collector system comprised of an edge drain and outlet pipe. In older pavements, the subdrainage system consists of only an edge drain and outlet pipe.

As referenced in Chapter 2, a number of research studies have been conducted to improve material properties associated with base/subbase layers. These studies have resulted in the development of permeable open graded drainage layers having a low percentage of fines. Edge drains receive water from the base/subbase layers and discharge it outside of the pavement system through outlet pipes. Cedergren et al. (1972) and Moulton (1980) have prepared guidelines and procedures for the design and construction of collector systems. But, literature on inspection procedures, cleaning and maintenance of edge drains is limited. Dempsey et al. (1982) described a system for jet cleaning conventional pipe edge drains. California (Wells, 1985) and Iowa (Steffes et al., 1991) have standard plans incorporated into their specifications for the cleanout and inspection of pipe edge drains. There are no cleaning

procedures for prefabricated edge drains (PFEDs).

To maintain subdrainage effectiveness, edge drains should be inspected both inside and outside. This chapter describes the inspection of existing subdrainage collector systems through external visual inspection in combination with a probe for internal inspection.

Study Objectives

This task was aimed at observing and recording distresses both around and within existing subdrainage collector systems. Results of the study will help the Indiana Department of Transportation (INDOT) better plan the construction and maintenance of edge drains.

The objectives of this study included:

1. inspecting existing types of edge drains in Indiana with regard to their performance and operation,
2. monitoring conditions inside edge drains by means of a video probe,
3. preparing a video of significant observations made during inspection, and
4. developing a methodology for inspection of underdrains.

For the study, a comprehensive field survey was initiated to locate sections with the two basic types of subdrainage collector systems used in the state. These are the perforated pipe edge drains and geotextile fin drains. To achieve a comparative evaluation of performance, drains ten years and

older and drains placed for newly built road sections less than four years old were incorporated into the study. A total of seventy underdrains and fin drains were inspected through their outlet pipes. Visual and camera observations were recorded for these drains. A list of the surveyed sections and their corresponding type of collector systems is given in Table 3.1.

Inspection of Existing Subdrainage Systems

Site Information

Prior to inspection of the edge drains, specific information was needed for the selected sites. This was achieved through Project Log Records and Construction Plans. Log Records contain information on highway classification, route number, county and district in which the section is located, project and contract numbers, contract length and project location.

Construction plans helped in determining edge drain locations in the pavement sections and in determining types and sizes of these edge drains. Additionally, information on pavement cross sections and grades were also obtained from the construction plans. Edge drain design, placement and construction details used by different state highway agencies vary. In Indiana, a typical pipe edge drain design used for both old and new construction projects is shown in Figure 3.1.

Table 3.1 Summary of collector systems inspected in Indiana

ROUTE NUMBER	COUNTY	TYPE OF COLLECTOR	NO. OF DRAINS INSPECTED
I-64	CRAWFORD	PIPE	12
I-164	VANDERBURG	FIN	4
I-65	SEYMOUR	FIN	4
US-30	LAPORTE	FIN	3
US-31	ST. JOSEPH	FIN	3
US-31	HAMILTON	PIPE	8
US-36	HENDRICKS	PIPE	5
US-41	SULLIVAN	FIN	9
US-50	DAVIESS	PIPE	3
SR-3	ALLEN/DEKALB	PIPE	4
SR-9	NOBLE	PIPE	3
SR-37	HAMILTON	PIPE	12
SR-38	TIPPECANOE	PIPE	3
SR-63	VERMILLION	PIPE	4
SR-469	ALLEN	PIPE	5

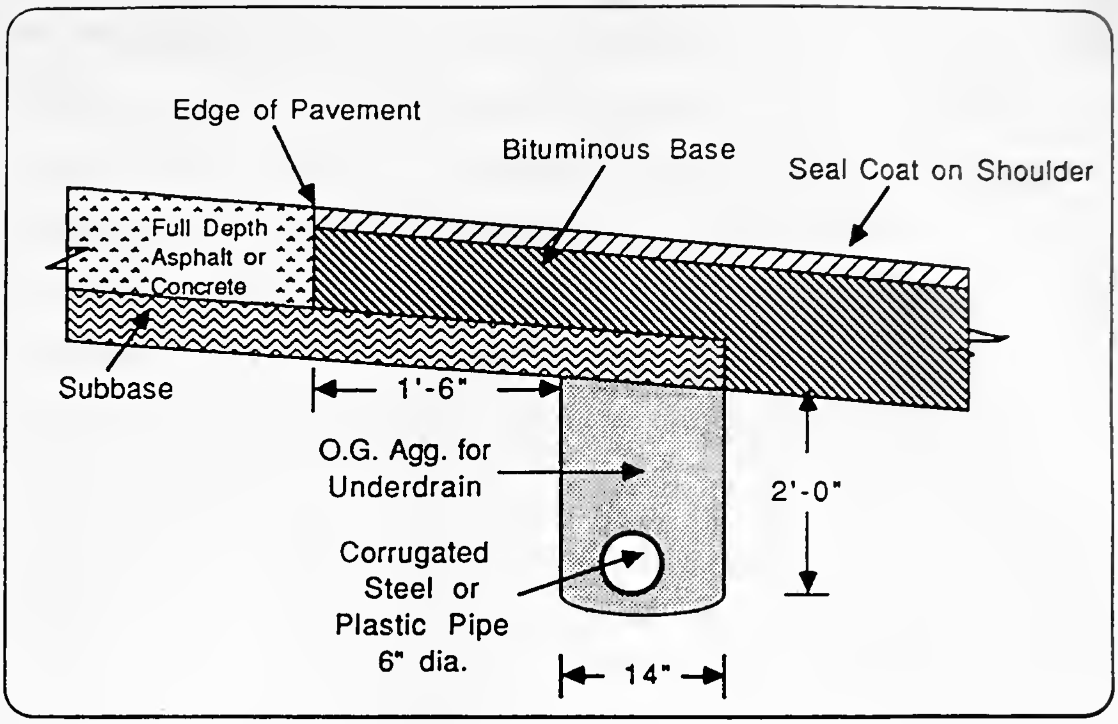


Figure 3.1 Cross section of underdrain used in Indiana

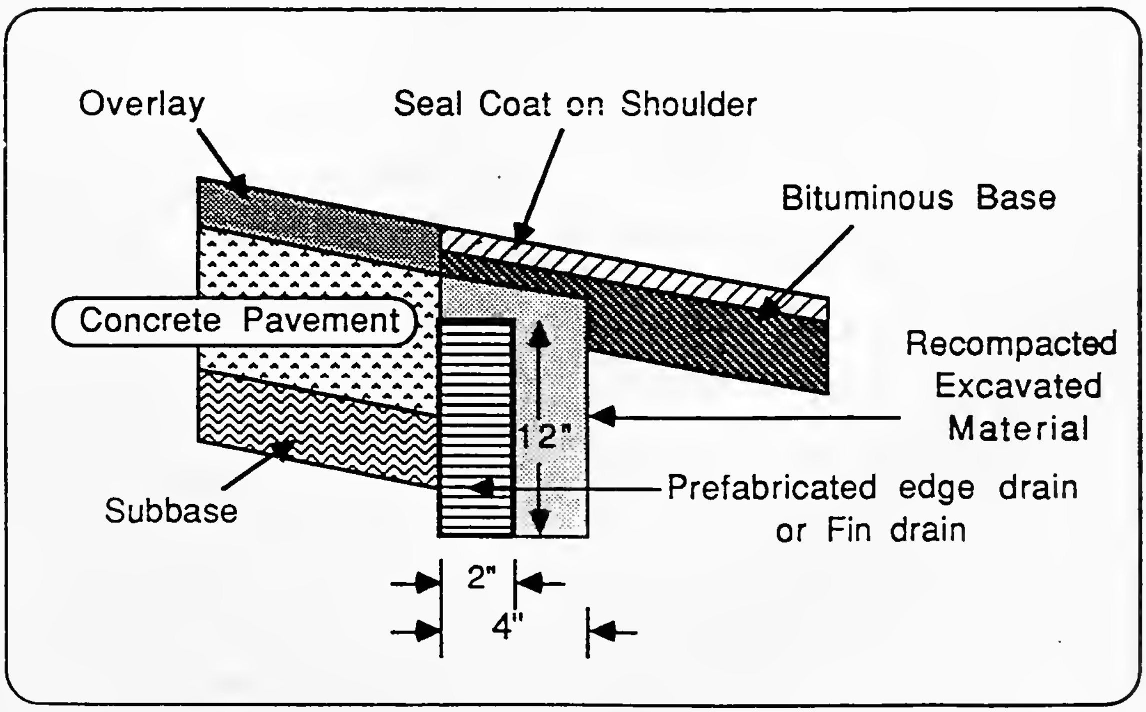


Figure 3.2 Cross section of fin drain used in Indiana

This consists of a trench 18 inches wide by 30 inches deep. A perforated pipe is placed at the bottom of the trench to a required depth and the trench backfilled with Indiana size No.8 aggregate. Use of a geotextile filter as a trench liner or pipe wrap were not encountered in the sections included in this study. For retrofit and overlay projects, a prefabricated edge drain or fin drain is used and is connected to the outside by a 4 inch diameter plastic outlet pipe (Figure 3.2). Pipe underdrains are either located at the edge of the pavement under the shoulder or at any intermediate point beneath the shoulder, whereas fin drains are located next to the pavement at the pavement-shoulder joint. Location of the drain helps in determining in advance the length of the outlet pipe the inspection probe has to traverse before making a bend into the collector pipe.

Condition Evaluation

As part of the edge drain inspection process a pavement condition survey was conducted. The objective of these condition surveys was to quantify the extent of pavement deficiencies as related to the condition of the drainage facilities. Evidence of distresses such as pumping, alligator cracking and joint cracking could be related to poor subdrainage. Information gathered would supplement the inspection of edge drains in setting maintenance strategies for subdrainage rehabilitation.

Condition surveys was performed using the distress identification procedure developed by Shahin, et al. (1979). For newly constructed or overlaid sections, it would have been trivial to survey these pavements, therefore only edge drains were inspected. Pumping stains and bleeding of water from overlaid concrete pavement sections were noted at sites where edge drain outlets were either buried or clogged. A sample of the condition survey forms is shown in Figure 3.3.

Equipment for Inspection

Bore Hole Camera System

Internal inspection of edge drains is conducted with a videoimagescope or borehole camera. For this project, a market survey was made to find a camera system that would allow effective inspection of either four or six inch diameter edge drains and/or outlet pipes. Four systems were considered.

Two Olympus camera systems were evaluated. The first system consists of a 3/4 inch (20mm) diameter videoimagescope that is pushed inside a pipe edge drain through the outlet pipe to a working length of 70 feet (22 m). It has an interior 100 degree field of view that can be recorded on video. The light guide is built around the scope and is controlled by a portable light source. The system is shown in Figure 3.4.

The second Olympus system allows a single lens reflex camera to be attached to a rigid borescope. The light guide at

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-31 BYPASS, SOUTH BEND SECTION NB
DATE 8/17/91 SAMPLE UNIT 1
SURVEYED BY Z. AHMED AREA OF SAMPLE 24'x 150'

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH: 24'

EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

	TYPE →	8	10	7			
QUANTITY & SEVERITY		22 L	100 L	50 L			
		100 L	12 L	50 M			
		20 L	6 L	6 L			
TOTAL SEVERITY	L	144	118	56			
	M			50			
	H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	2.33	L	4
7	2.08	M	12
8	6.0	L	10
10	4.91	L	11
q= 3	TOTAL DEDUCT VALUE		37
CORRECTED DEDUCT VALUE (CDV)			23

PCI = 100 − CDV = 77

RATING = V. Good.

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

Overall Mean CDV = 80.2
Rating :- Very Good

Comments:-
Less than 1/8" rut depth

The section chosen was 1000 ft length x 24' wide: corresponding to the area around the instrumented site.

Figure 3.3 A sample condition survey form

Figure 3.4 Inspection system for pipe edge drains (photo, courtesy of Olympus Corporation)

the tip of the borescope is controlled by a portable light supply. This system can be used to pierce through the fabric of the fin drain and record an interior view of the drain. The system is shown in Figure 3.5.

The PLS system uses a compact TV probe with an outside diameter of 1.62 inch (40mm) and length of 3 inches (76mm). It comes with 150 feet (46m) of camera cable, camera guide skids, push rod and reel and a control unit which includes a 9 inch color TV monitor/recorder. The system comes with two light heads, which are interchangeable. A view of the system is shown in Figure 3.6.

The final system considered (Cues) has a black and white camera system with built-in, field replaceable lighting system. The camera is 2.75 inches (70mm) in diameter tapering to 0.82 inches (21mm) at the ends and is mounted on a skid assembly. This system also comes with 150 feet of push cable mounted on a rotating drum and has to be connected to an external video recorder to record the image seen from the TV housed in the control unit. The system is shown in Figure 3.7.

A decision was made to purchase the PLS system and was based on the length of the cable available, the color image capability and the provision of the push rod and reel which would aid in pushing the probe manually through the pipe in the absence of a motorized unit. For inspection of fin drains, an Olympus borescope provided by Monsanto was used, as the company also wanted to evaluate the performance of their fin

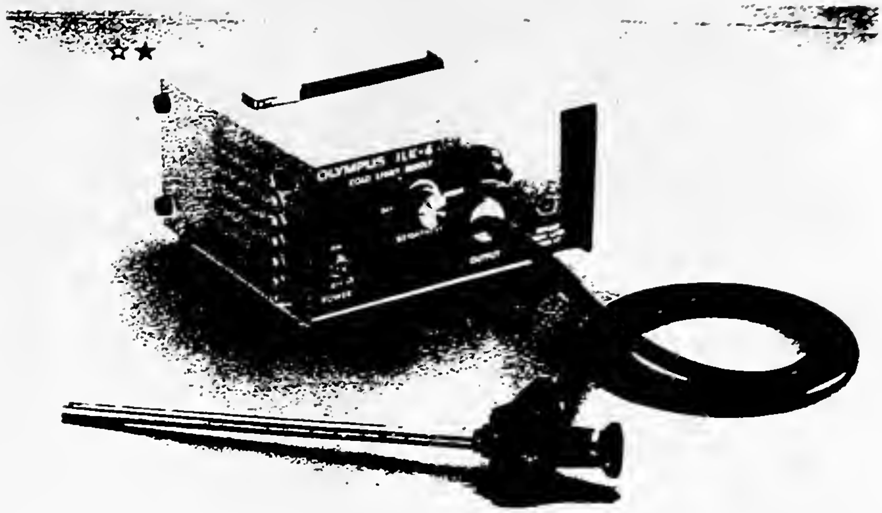


Figure 3.5 Inspection system for prefabricated edge drains (photo, courtesy of Olympus Corporation)

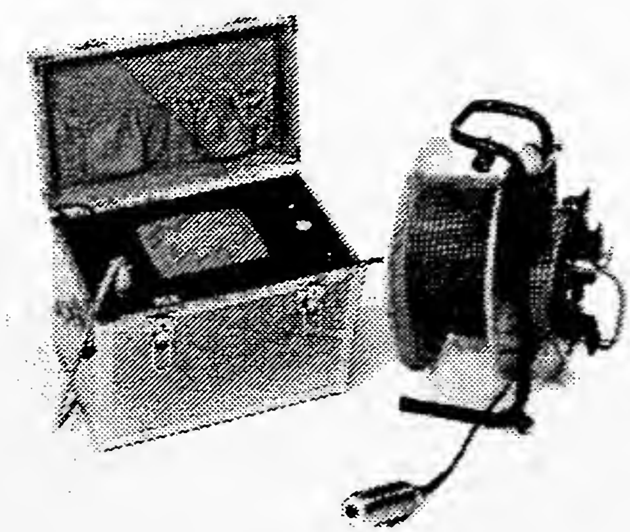


Figure 3.6 PLS inspection system for pipe drains (photo, courtesy of PLS Corporation)

Figure 3.7 Cues inspection systme for pipe drains
(photo, courtesy of Cues System)

drain product.

A trial run was made in the laboratory with a "T" type pipe joint prior to field application. This step was taken to develop techniques for camera operation, insertion and extraction. Two problems were encountered. One problem was that the guide attached to the camera head could not be easily manuevered through the 90 degree bend. The guide and attached camera was forced through the bend, but could not be extracted. The second problem was that the guide, because of its smaller diameter, "walked" up the sides of the pipe wall while being pushed. Another problem which was visualized was that for corrugated pipes, the probe would not ride smoothly over the corrugations, resulting in a distorted image. Modifications were subsequently made to the guides which are shown in Figure 3.8.

Auxiliary Equipment

Equipment used for field inspection, in addition to the camera system, were a generator, weed eater, metal detector and miscellaneous tools and equipment like shovels, crow bars, tapes, etc. To operate the camera with both types of light heads, a portable generator with a minimum rating of 750 watts is required. For this study, a Honda generator with a maximum output of 1000 watts was used. The unit is compact, quiet and easy to transport.

A weed eater is effective in clearing the area around the

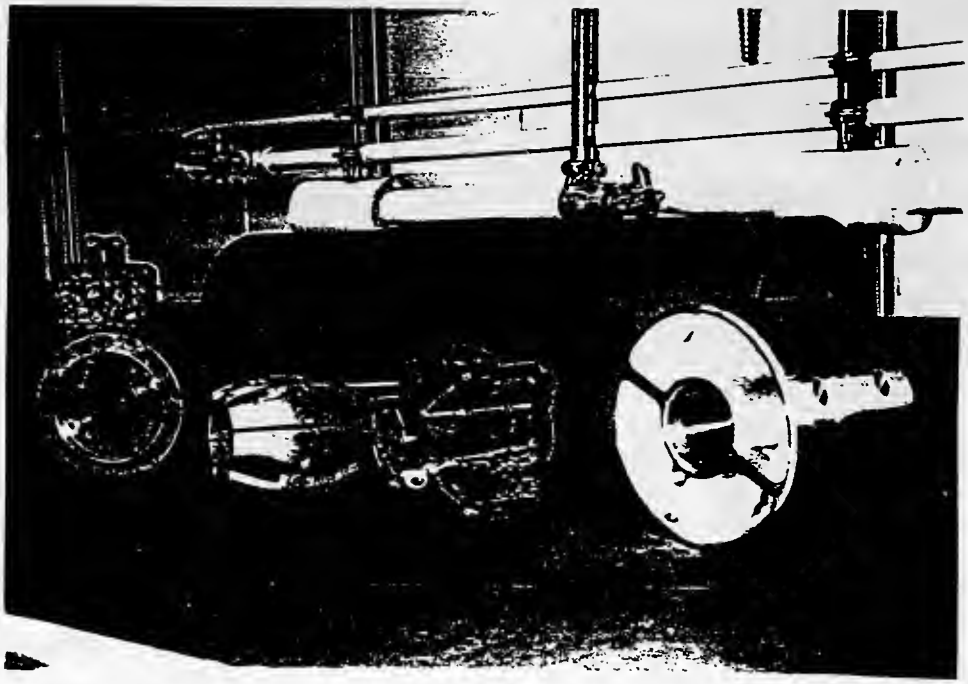


Figure 3.8 Types of guide sleeves used

pipe outlet. For a majority of the drains inspected, tall grass and vegetation, as shown in Figure 3.9, were encountered that not only obstructed the flow of water but also made it difficult to inspect the outlet.

During the initial survey to locate the underdrain outlets, considerable difficulty was encountered on highway sections in service for more than ten years. In some cases, outlets were not marked and were not found at the stations listed on the construction plans. Outlets were found buried by landscaping of adjacent areas. To offset this problem, a metal detector was used with success.

Visual Observations

Drain inspection is carried out through visual and camera observations. A visual observation is made of the condition of the outlet pipe opening and the surrounding area. A number of problems were encountered and are discussed.

Outlet Pipe Slope

A general check of outlet pipe slope was made by measuring the vertical depth of the outlet pipe from the pavement surface and checking this measurement with construction plans. In case of flat terrain or longitudinal grades less than 1%, the outlets were found to have a negative or reverse slope. For this condition, ponded water was observed inside the outlets in the camera inspections.

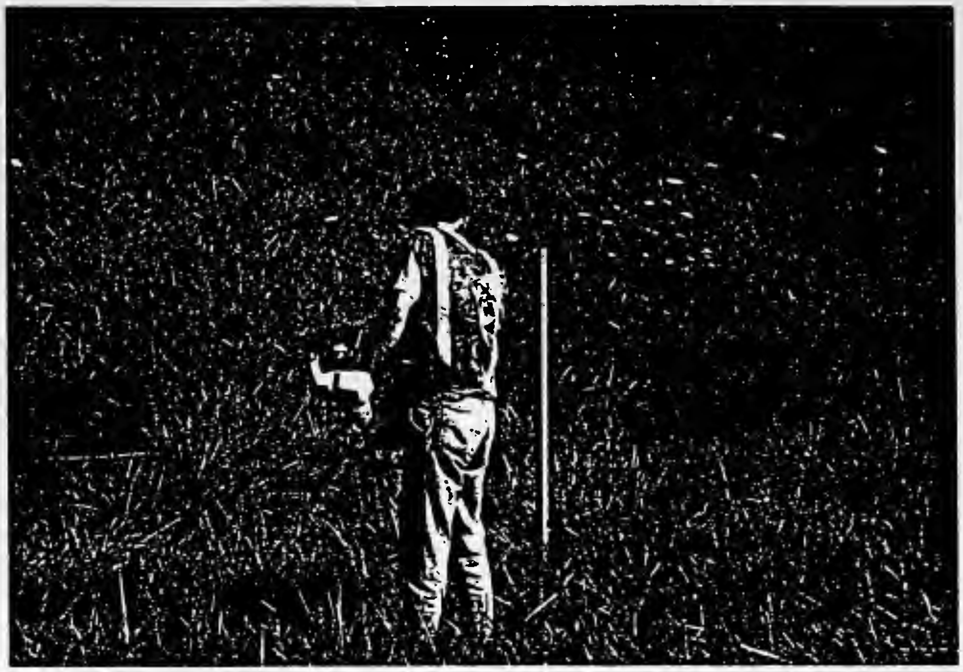


Figure 3.9 Clearing vegetation

Outlet Condition

A frequent outlet condition found was that pipes were exposed for some length (Figure 3.10), or outlets were crushed (Figure 3.11). Crushed outlet pipes become clogged over time, rendering the drainage system ineffective. Crushing is associated with erosion of soil on flat slopes from around the outlet and operation of mowing equipment on the embankments.

Markers and Rodent Screens

In the majority of cases, outlet markers were not present or were bent or lying beside the outlet pipes. Rodent screens on outlet pipes were present in most of the sections inspected. Three outlet screen designs were found. The most common one was a mesh type screen (Figure 3.12), followed by a spear type (Figure 3.13) and a spiral type (Figure 3.14). The spear type screen did not cover the outlet pipe opening and could be easily lifted, allowing rodents and small animals to access the pipe.

Vegetation

A main difficulty in underdrain inspection is the growth of vegetation around outlet pipes. Moisture is retained around the pipe rendering placement of equipment for inspection difficult. Standing grass around outlets creates a barrier for flow from the pipes. Accumulation of sedimentation and vegetation growth progressively block the pipe from outside.

Figure 3.10 View of exposed and damaged outlet pipe

Figure 3.11 View of crushed outlet pipe

Figure 3.12 Mesh rodent screen

Figure 3.13 Spear type rodent screen

Figure 3.14 Spiral rodent screen

When vegetation was removed (Figure 3.15), any water standing in the outlet pipe started to flow.

Headwall And Erosion Control Apron

The presence of a headwall and an erosion control apron or rip-rap protection around outlet pipes was observed to have a positive effect on water outflow. In the absence of this protection, the soil around the outlet pipe erodes (Figure 3.16), exposing the pipe. The connection between the outlet pipe and the headwall may also be broken. A headwall or lined ditch at the outlet was also found to be effective in restricting the growth of vegetation around the outlet.

Camera Observations

The second stage in the inspection process involved use of the camera systems for internal inspection of edge drains, geo-composite fin drains and outlet pipes. Pipe edge drains were inspected by the PLS camera system. The same system was used to inspect outlet pipes for fin drains. Different colored plastic tape was tied to the camera cable and push rod at ten feet intervals for the purpose of determining the length of probe travel. This helped in ascertaining the distance to distresses described later and to determine where resistance to further advance was met.

Prefabricated edge drains (Monsanto) were inspected with the help of equipment and personnel provided by INDOT and the

Figure 3.15 Clearing grass at outlet pipe

Figure 3.16 Erosion around newly constructed outlet pipe

Monsanto Company. First a section of the shoulder next to the pavement-shoulder joint, about 15 inches square, was excavated. The excavation was made to a depth just above the top of the drain and then manual excavation was used to expose the top of the fin drain. The shaft of the Olympus borescope system was then inserted through the fabric into the core. Visual inspection was made of the conditions inside the core and a photographic record was made with a reflex camera which was fitted to the borescope with an adapter. A setup of the borescope is shown in Figure 3.17.

The condition and distresses observed for both types of drainage systems are described hereafter.

Joint Connections

Inspection of pipe interiors revealed that the joint connections are the most distressed part of the system. Specifications require the coupling to be flush with the pipe, but inspections revealed in some cases the absence of couplings and connections made by bending the pipe ends and forcing the bent end into the adjacent section. Plant roots were often observed to be penetrating through such connections into the pipe.

Flow of Water

In newer sections, those built within the last two or three years, water was found to be flowing freely both inside the underdrain and the outlet pipes. In older sections,

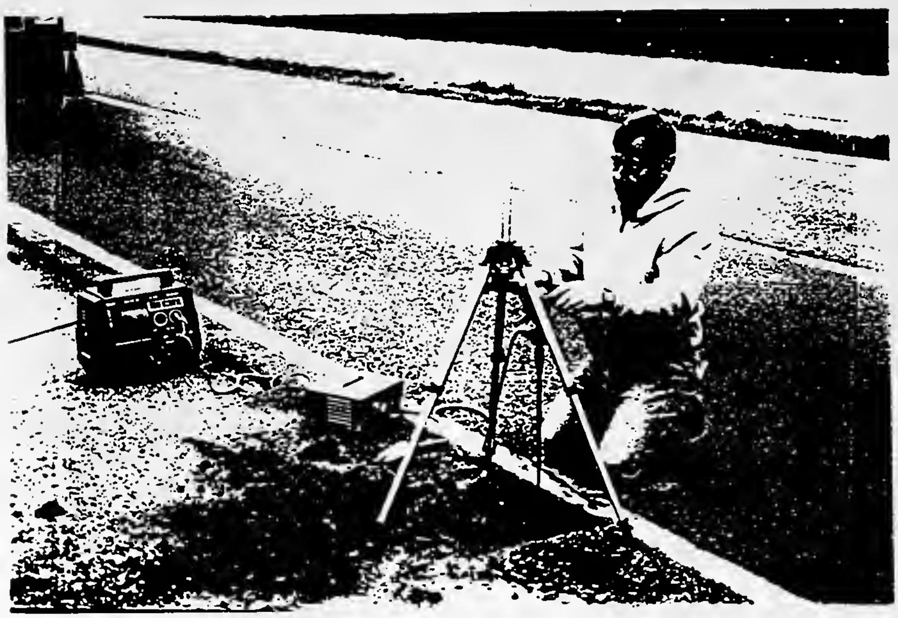


Figure 3.17 Setup of Olympus borescope system

standing water with fine particles in suspension was observed where there was a sag in the pipe along its length, or due to negative slopes for some outlet pipes. These deficiencies could be attributed to improper care during construction, as a result of settlement, or loads from vehicles or mowing equipment. Inspections made immediately after a rainfall event showed that water flows with high velocity in sections having a positive slope for outlet pipes or at sag points along the highway (Figure 3.18). This helped in flushing out fine particles entering the drain through slots and openings.

Pipe Corrosion

Most of the corrugated steel pipe underdrains viewed through the camera showed significant corrosion. This can be attributed to dissolved salts or other chemicals. This type of distress becomes more severe when there is standing water inside the pipe as it allows ample time for the dissolved chemicals to react with the pipe metal. In some of the inspected pipes, the corrosion severity had resulted in development of cavities and openings in the pipes. Ultimately, the pipe and without flow for a period of time, the pipe system becomes plugged. In one of the drains inspected, gravel used in the embankment was observed at the outlet (Figure 3.19). Plastic pipes inspected were free from this form of distress.

Figure 3.18 Water flowing freely from an outlet pipe

Figure 3.19 Gravel from a punctured outlet pipe

Figure 3.20 Sedimentation deposits in an exposed fin drain

Sedimentation In Fin Drains

Some of the inspected fin drains showed sedimentation at the bottom of the fabric. Typically the fin drains are 12 inches in height. However, in several cases, the shaft of the borescope could not be pushed beyond a maximum depth of 10 inches. This was attributed to sedimentation. A section of the fin drain was removed from along Interstate 65. The cross section of the drain which had been inplace for four years showed sedimentation deposits to a depth of 3 inches (Figure 3.20). This section of I-65 has a dense graded aggregate base. Fin drains installed along I-65 having bituminous stabilized subbases showed less of this problem and water flowed freely immediately after rainfall events.

Another form of sedimentation deposit observed was along the pavement side of the fabric. Migration of aggregate base fines had resulted in the formation of a filter cake along the fabric (Figure 3.21). As there is no technique yet to remove this sedimentation deposit, it would eventually affect the ability of the fin drain to remove water from the pavement system.

Fin Drain Buckling

Buckling was observed at most points along the fin drains with the aid of the borescope camera. The cuspations of the drain core would seem to arch along the horizontal plane. This was more pronounced at transverse joints along concrete

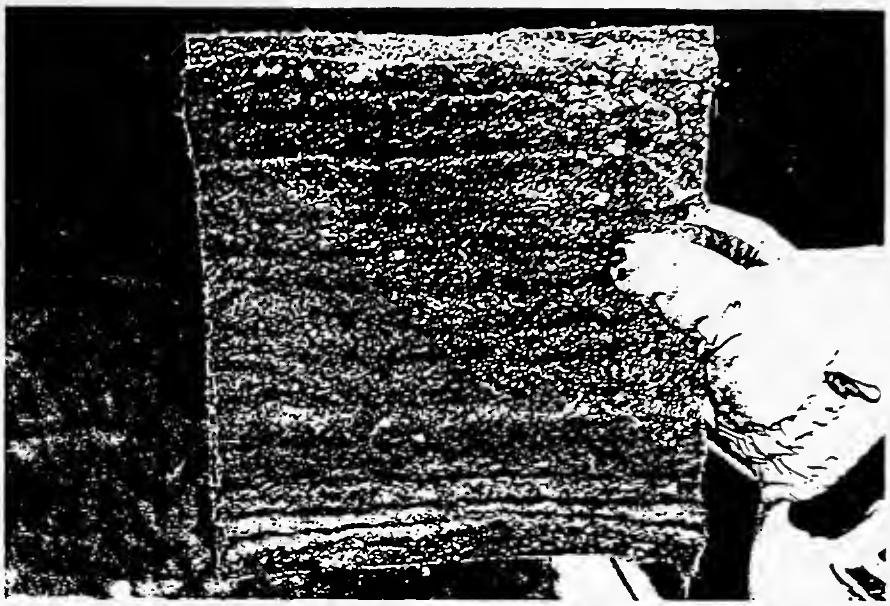


Figure 3.21 Fine deposits on outer fabric of fin drain

pavements. Section exposed at the joint showed the width of adjacent concrete slabs varying by as much as 1 to 2 inches. As the drain is placed immediately adjacent to the pavement/shoulder joint, projection of adjacent slabs causes the drain to bend in a horizontal plane. As a result, cuspations of the drain core bend inwards as shown in Figure 3.22, and tear or puncture the fabric. This in turn reduces the core flow capability of the drain.

A form of fin drain distress observed in the vertical plane is termed J-buckling (Figure 3.23). This is attributed to the design of the Monsanto fin drain as shown earlier in Figure 2.9. The drain core has a perforated base on one side with cuspations projecting from the base. The fabric is wrapped around the core. The cuspated side of the core is susceptible to buckling when loaded vertically. Such a vertical load is applied during trench backfilling and compaction. Also, the outlet pipe connections are not made at the same time the drain is installed. Thus the trench has to be reexcavated at the point of joint connections in order to connect the outlet pipes. Backfilling and compaction results in the drain buckling along its bottom edge, especially at the joints. This was observed with the PLS camera system while checking the fin drain outlet pipes.

Connector Angle

The type of edge drain to outlet pipe connector has a

Figure 3.22 Roll over and fabric intrusion in fin drain

Figure 3.23 Exposed fin drain indicating J-Buckling

significant impact on inspection, maintenance, and cleaning of subdrainage pipes. Connector angles have to be large enough to allow movement of the inspection camera probe. This is also true for injection cleaning equipment which may be utilized to clean the interior of the pipe. Evaluation of the existing drain connectors through the camera system has shown that the probe could be easily moved into an underdrain through the outlet connector if a Y-connector is used instead of a T-connector. For new underdrains inspected, it was observed that connectors sweeping an angle of 60 degrees on a horizontal plane proved to be the most efficient for movement of the camera through the joint.

Subdrain Inspection Process

A detailed account has been given of equipment and processes used to inspect subdrainage collector system. Also various types of distresses and deficiencies observed both visually and with the camera system have been described. This section logically summarizes the requirements of an inspection process.

The requirements of an inspection process includes:

a. Site information (inventory and as built records).

b. Condition evaluation of roadway.

c. Visual and Camera Observations.

d. Information logging.

Site Information

Accurate site information is vital to the inspection procedure. Information on the route, location, direction, project and contract numbers and year of construction can be obtained through inventory data maintained by INDOT. Construction plans help in determining the exact locations of outlets. This information is useful for periodic inspections of the same section.

Condition Evaluation

General observation of a pavements condition prior to drainage inspection gives an indication of distresses associated with trapped moisture. Moisture related distresses can be isolated from the overall condition of the pavement and their effect on the performance of subdrainage system quantified. The observations will supplement those made by visual and camera observations.

Visual and Camera Observations

Features and the geometry of outlet pipes are observed visually and noted as well as any unusual feature which would help in assessing the effectiveness or problem areas associated with a collector system. Camera observations are made using the PLS system for pipe edge drains and the Olympus system for prefabricated edge drains. With the PLS system, observing and recording take place simultaneously, whereas

with the Olympus system, the conditions inside the drain core are observed through a view port attached to the borescope and then recorded with a camera.

Information Logging

For ease and convenience of recording information, a standard inspection report form has been developed. A completed sample form is shown in Figure 3.24. This form provides for an organized recording of the data. Supplemental information in the form of photographs also aids in documenting any deficiencies not listed or recorded to obtain an overall picture of the site conditions.

A final report should include the inspection report form, photographs, narrative descriptions and other relevant information. This will provide a permanent record which can be used for reference in periodic inspections of both existing and retrofitted drains.

Chapter Summary

A method of inspecting subdrainage collector systems has been described. The method basically utilizes an imagescope to evaluate and monitor the performance of existing and retrofitted subdrainage systems. The information will lead to improved pavement maintenance, design, material specifications, construction specifications, and performance of subdrainage systems.

COLLECTOR SYSTEM INSPECTION FORM

SITE INFORMATION

DISTRICT VINCENNES COUNTY CRAWFORD HWY No. I-64 DIRECTION EB

PROJECT No. I-64-2(31)78 CONTRACT No. R-10230 CONTRACT LENGTH 4.5 (MILES)

PROJECT LOCATION FROM PERRY-CRAWFORD CO. LINE TO 1.5 MILES WEST OF SR-37

DATE OF INSPECTION 9/9/90 INSPECTED BY Z. AHMED & N. KHAN

DRAIN No. 2 DRAIN LOCATION 2nd DRAIN FROM PERRY CO LINE SIGN

DISTANCE FROM PREVIOUS DRAIN ______ (IN FEET) 0.2 (IN MILES)

OBSERVATIONAL INFORMATION

LOCATION OF COLLECTOR: 1. END OF PAVEMENT 2. END OF SHOULDER 3. INTERMEDIATE POINT

TYPE OF COLLECTOR SYSTEM: [✓] UNDERDRAIN OR K-PIPE [ ] FIN OR X-DRAIN

TYPE OF UNDERDRAIN PIPE: (CIRCLE ONE) 1. CORRUGATED STEEL 2. BITUMINOUS COATED CORRUGATED STEEL 3. PLASTIC CORRUGATED 4. CLAY 5. OTHER ______

TYPE OF OUTLET PIPE: (CIRCLE ONE) 1. CORRUGATED STEEL 2. BITUMINOUS COATED CORRUGATED STEEL 3. PLASTIC PLAIN 4. PVC CORRUGATED PLASTIC 5. OTHER ______

VERTICAL DEPTH OF OUTLET PIPE FROM PAVEMENT SURFACE 2.5 (FEET)

SIZE OF OUTLET PIPE: 6" DIA. 4" DIA. OTHER ______

SLOPE OF OUTLET PIPE: FORWARD REVERSE FLAT

CONDITION OF OUTLET OPENING: FULL SIZE PARTIAL DAMAGED

SCREEN PRESENT: YES NO TYPE MESH.

OUTLET MARKER PRESENT: YES NO CONDITION BENT

HEAD WALL PRESENT: YES NO CONDITION ______

EROSION CONTROL APRON PRESENT: YES NO TYPE LINED DITCH

CONDITION OF VEGETATION ON EMBANKMENT: MOWED NOT MOWED

MOVEMENT OF PROBE: FREE PARTIAL BLOCKED

WATER PRESENT INSIDE DRAIN: YES NO

IF YES: FREE FLOWING STANDING

DISTANCE TRAVERSED BY PROBE 54 (FEET)

CAMERA OBSERVATIONS: CORROSION OBSERVED ON SIDE WALLS; STANDING WATER AT SAG OF PIPE FROM 50 FT. ONWARDS. NO BLOCKAGE OBSERVED

ADDITIONAL OBSERVATIONS: SECTION AT START OF DOWNHILL SLOPE

Figure 3.24 Sample of completed inspection report form

The camera system can serve as a valuable tool for inspection of newly built drains prior to the project being handed over by the contractor to the state agency. Damage or distress due to construction practices can be located. Modifications of the original camera equipment that have been described will result in more efficient and trouble free operation. Major findings of the study and recommendations for improvement are listed in Chapter 7.

CHAPTER 4 - FIELD TESTING AND INSTRUMENTATION

Background

A number of simulation studies have been made to assess pavement performance due to variation of moisture in subbases and subgrades (Corey, et al., 1965; Wallace, 1977; Dempsey, 1979; Markow, 1982). Models based on these studies tend to incorporate assumed values of parameters for evaluation. Such complex evaluation procedures for moisture movement have underscored the need of accurately determining moisture conditions in pavements. Data from on-site instrumentation can be used to validate analytical models as well as to calibrate model response variables.

As part of this research study, a computer program 'PURDRAIN' was developed (Espinoza et al., 1993) to provide a rational tool for the analysis of pavement drainage systems for varying geometric, material and boundary characteristics. This chapter describes the development and application of various instruments to field sections. The purpose of instrumentation was to monitor moisture movement in pavement layers and to provide data for validation and calibration of the program 'PURDRAIN'.

Overview of PURDRAIN

PURDRAIN is a computer program which can analyze moisture flow in an unsaturated porous media. The program is written in PASCAL (Borland Int., 1988) and provides a user friendly environment for defining input parameters and generation of moisture migration predictions.

The numerical model implemented in the program is based on the theory of transient moisture flow in unsaturated porous media. The method of analysis incorporates two models of soil-water retention and conductivity. These are the Brooks & Corey Model (Brooks & Corey, 1964) and the Van Genuchten Model (Van Genuchten, 1980).

Brooks and Corey (1964) described the relationship between effective degree of saturation 'S_e' and matric suction 'ψ' by:

$$S_e = \left(\frac{\psi}{PB}\right)^{-\frac{1}{\nu}} \quad for \quad \psi \geq PB \qquad 4.1$$

$$S_e = 1 \quad for \quad \psi < PB \qquad 4.2$$

where: PB = bubbling pressure of the soil

ν = pore size distribution index

The effective degree of saturation 'S_e' is related to the volumetric moisture content 'θ' by

$$S_e = \frac{(\theta - \theta_0)}{(\theta_r - \theta_0)} \qquad 4.3$$

where: θ_r = volumetric moisture content at resaturation

θ_0 = irreducible volumetric moisture content

The values of θ, θ_r, and θ_0 can be obtained by determining capillary-moisture relationships of soils. Laboratory tests to obtain these parameters are described in detail in Chapter 5.

Van Genuchten proposed the following empirical relation between matric suction 'ψ' and effective degree of saturation 'S_e':

$$S_e=\frac{1}{(1+(\alpha\psi)^{\beta})^{\gamma}} \quad for \quad \psi\geq 0 \tag{4.4}$$

$$S_e=1 \quad for \quad \psi<0 \tag{4.5}$$

where α has the units of inverse of piezometric head whereas β and γ are dimensionless parameters. Evaluation of the dimensionless parameters is described in Chapter 5.

PURDRAIN is able to handle one and two-dimensional analyses of moisture infiltration and subsequent redistribution in a multi-layer system. The program evaluates relative degrees of saturation, piezometric heads and moisture contents. Pavement systems with various geometry, material and hydraulic properties can be modeled. Outflow from a pavement subdrainage system can also be predicted for precipitation events on a time basis.

Performance criteria of existing pavement subdrainage systems can be evaluated and prediction made of the behavior of new systems before implementation. A detailed description of the program and the mathematical formulation of the

numerical model is given in a separate report (Espinoza, et al., 1993).

Test Site Selection

Drainage studies were conducted to determine the influence of precipitation, pavement type and collector system configuration on subsurface drainage. This was achieved by instrumenting and measuring subbase and subgrade moisture profiles and system flow volumes. Pavement test sections that were instrumented were selected based on the following criteria.

1. Locating sites in the northern and southern climatic regions of the state (Yoder and Colucci-Rios, 1980).
2. Considering of pavement sections with Average Annual Daily Traffic (AADT) greater than 3000 and daily truck traffic greater than 1000. These criteria were selected because of the effect of high traffic volumes and heavy wheel loads on the development of moisture accelerated distresses.
3. Including asphalt and concrete pavements.
4. Including sections incorporating pipe edge drains and prefabricated edge drains.

The Indiana Road Inventory database was studied and a preliminary random selection made for sections meeting the above criteria. Information on base courses, drainage systems and highway profiles for the selected sections were obtained from Log Reports and Construction Plans available through

INDOT Program Development Division. Ten target sections were finally selected for which complete pavement and material information was available (Table 4.1). The candidate sections included two sections without edge drains. Figure 4.1 shows the selected section locations. Site specific information on the target sections is given in Tables 4.2 to 4.11. The target sections incorporate flexible, rigid and overlaid pavements. Typical cross sections of each pavement type are shown in Figures 4.2 to 4.4.

Subdrainage Instrumentation

Instrumentation was selected to achieve the modeling goal and to measure associated responses of hydraulic parameters to infiltration of moisture into the pavement system. As described earlier in Chapter 2, a literature review was conducted to identify instruments which could be used in monitoring pavement response to moisture infiltration. The instrumentation was selected based on precision, compatibility with the monitoring system, cost and field worthiness. It is always advantageous to select instruments which have been proven in the field, and to this end, recommendations on some of the instruments were taken from an experimental project sponsored by the FHWA to study drainage characteristics of concrete pavements (Baumgardner and Mathis, 1989). The present study is broader than the FHWA study and considers asphalt, concrete and composite pavements as well as pipe and

Figure 4.1 Geographic Location of Instrumented Sections

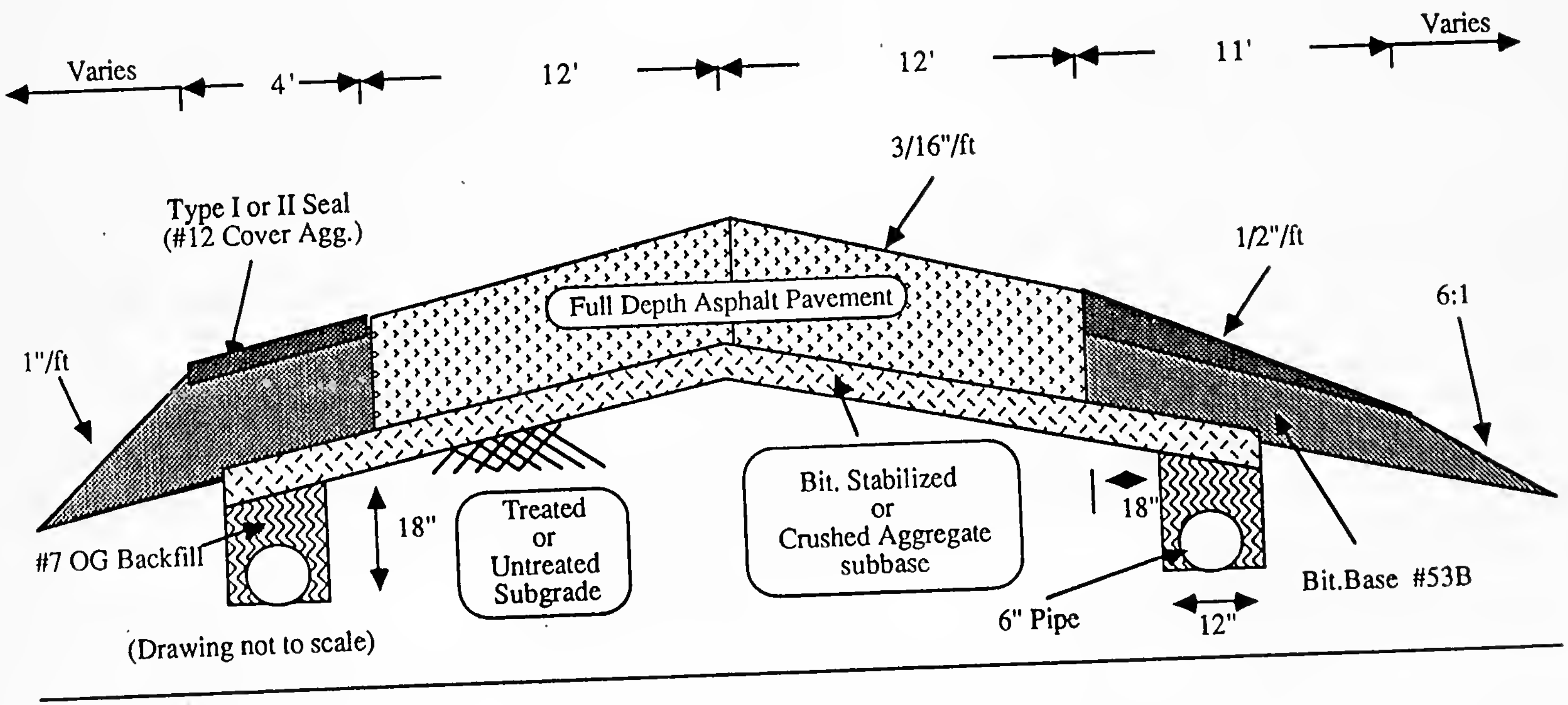


Figure 4.2 Typical Cross Section of Flexible Pavement

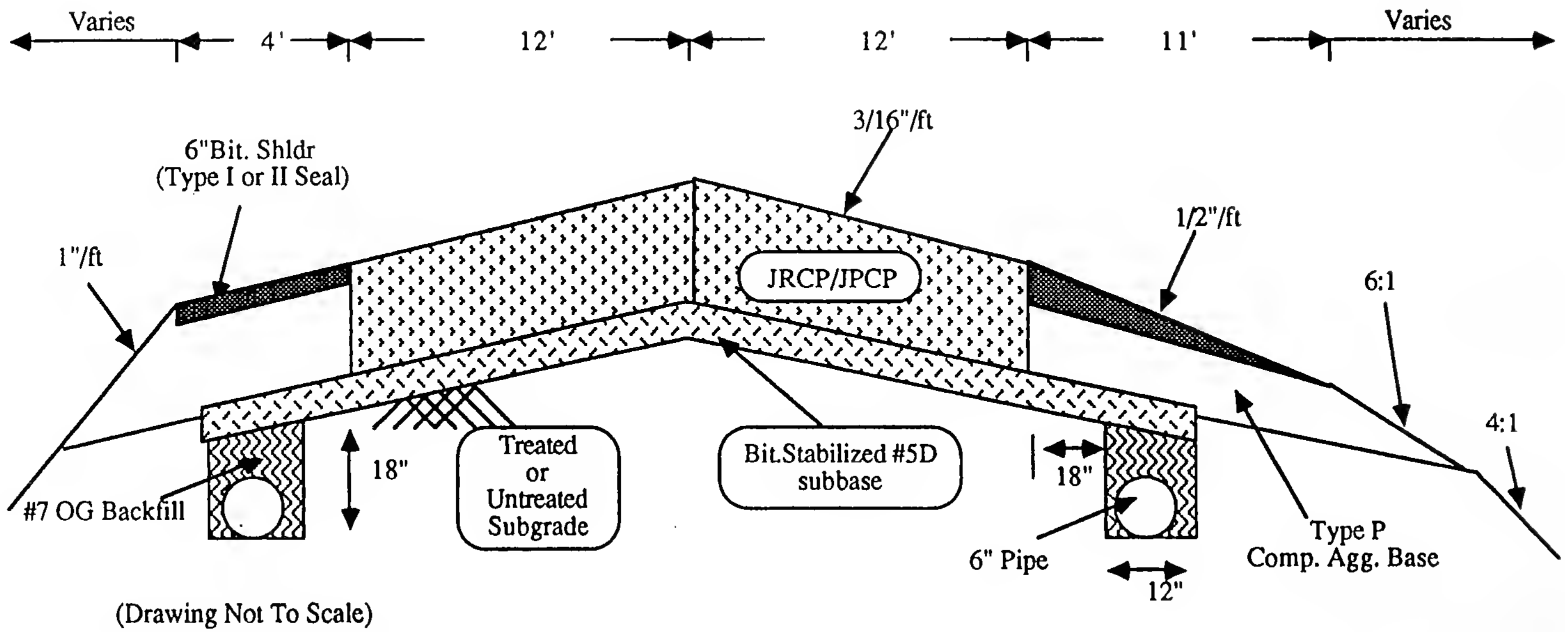


Figure 4.3 Typical Cross Section of Rigid Pavement

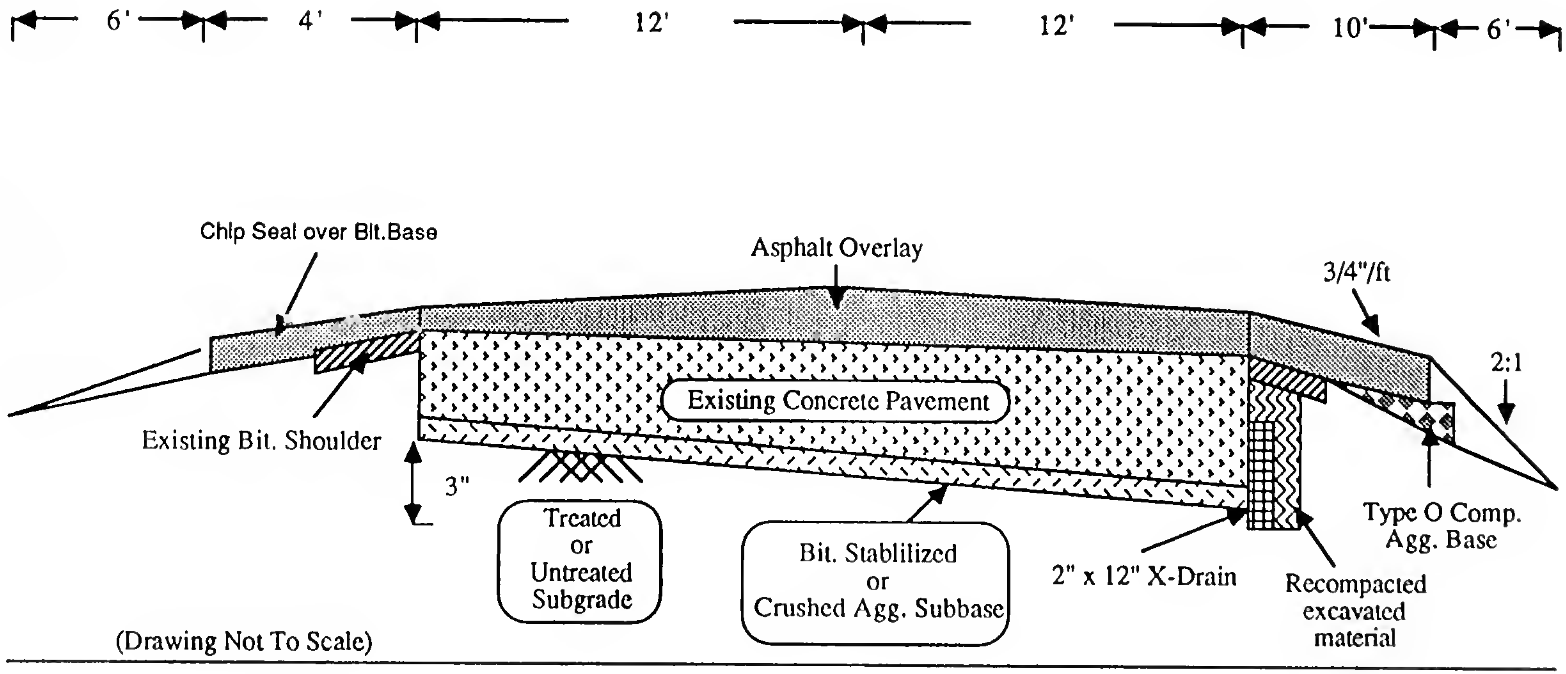


Figure 4.4 Typical Cross Section of Overlaid Pavement

Table 4.1 Instrumented Target Sections

SECTION NUMBER	ROUTE NUMBER	COUNTY	DISTRICT
1	US-31	HAMILTON	GREENFIELD
2	SR-37	HAMILTON	GREENFIELD
3	SR-37	LAWRENCE	VINCENNES
4	US-41	SULLIVAN	VINCENNES
5	US-30	LAPORTE	LAPORTE
6	US-31	ST.JOSEPH	LAPORTE
7	SR-9	NOBLE	FORT WAYNE
8	SR-43	TIPPECANOE	CRAWFORDSVILLE
9	SR-63	VERMILLION	CRAWFORDSVILLE
10	US-36	HENDRICKS	CRAWFORDSVILLE

Table 4.2 Test Section 1 Design Features

Instrumented Section Information

County /District: *Hamilton/Greenfield* Route No: *US-31, NB*

Contract No: (Old) *R-9357* Project No: *ST-F-222(9)*

(New) ______ Max. Grade : *3.00%*

Location: *0.4 miles north of I-465 Jct in Carmel near Indianapolis*

Station to Station: *283+60.00 546+52.57* Length: *4.983 Miles*

Year of Construction: *1975* Year of last major activity ______

AADT /Year *22030/1985* %Truck *15*

Design Information

Pavement X-section : (Circle one) 1. Asphalt 2. JPCP/JRCP 3. Asp. Overlay on JPCP/JRCP

Layer:	Material	Type	Thickness
Overlay			
Surface	*Concrete*	*JRCP*	*11"*
Base			
Subbase	*Bit. Stabilized*	*#5D*	*4 "*
Shoulder	*Bit.Base/Agg.*	*#5/Type O*	*6"/9"*

Joints Sealed: Yes $\boxed{\text{No}}$ Shoulder Sealed: $\boxed{\text{Yes}}$ No Type: *I(#12)*

Longitudinal Slope *1.2* % Cross Slope *1.3* %

Subgrade Information:

Soil Type *Sandy loam* Depth *24-48 inches*

Unified Classification *SM-SC*

AASHTO Classification *A-4(0)*

Collector System Information:

Type: (Circle one) 1. No drains 2. Underdrains 3. X-Drains (Geo-comp)

Distance of instrumented outlet from: Upstream outlet *1000 feet*

Downstream outlet *212 feet*

Special features: *Upstream and downstream sections slope towards inst. outlet*

Table 4.3 Test Section 2 Design Features

Instrumented Section Information

County /District: *Hamilton/Greenfield* Route No: *SR-37, SB*

Contract No: (Old) *R-3928* Project No: *F-824(3)*

(New) *R-12196* Max. Grade : *0.80%*

Location: *Section North of SR-32 Jct in Noblesville*

Station to Station: *910+00 - 1049+85* Length: *2.545 Miles*

Year of Construction: *1956* Year of last major activity *1981*

AADT /Year *9180/1985* %Truck *10*

Design Information

Pavement X-section : 1. Asphalt 2. JPCP/JRCP 3. Asp. Overlay on JPCP/JRCP
(Circle one)

Layer:	Material	Type	Thickness
Overlay			
Surface	*Asphalt*	*HAE*	*4"*
Base	*Macadam*	*Waterbound*	*8 3/4"*
Subbase	*Aggregate*	*#2stone*	*8"*
Shoulder	*Bit.Base/Crushed Agg*	*#5/Type P*	*3"/6"*

Joints Sealed: Yes No Shoulder Sealed: Yes No Type: *II*

Longitudinal Slope *0.07* % Cross Slope *1.5* %

Subgrade Information:

Soil Type *Sandy loam* Depth *24-36 inches*

Unified Classification *SM-SC*

AASHTO Classification *A-2-4*

Collector System Information:

Type: (Circle one) 1. No drains 2. Underdrains 3. X-Drains (Geo-comp)

Distance of instrumented outlet from: Upstream outlet *600 feet*

Downstream outlet *1000 feet*

Special features: *Groundwater flow at inst. section*

Table 4.4 Test Section 3 Design Features

Instrumented Section Information

County /District: *Lawrence/Vincennes* Route No: *SR-37, SB*

Contract No: (Old) *R-8886* Project No: *ST-F-819(2)*

(New) ______ Max. Grade : *3.00%*

Location: *b/w Bedford and Oolitic (inst. section near SR-58 Jct)*

Station to Station: *10+21 - 486+64* Length: *2.993 Miles*

Year of Construction: *1974* Year of last major activity ______

AADT /Year *16120/1985* %Truck *15*

Design Information

Pavement X-section : (Circle one) 1. Asphalt 2. JPCP/JRCP 3. Asp. Overlay on JPCP/JRCP

Layer:	Material	Type	Thickness
Overlay			
Surface	*Concrete*	*JRCP*	*10 1/2"*
Base			
Subbase	*Bit. Stabilized*	*#5D*	*4 1/2"*
Shoulder	*Bit.Base/Agg.*	*#5/Type O*	*3"/5"*

Joints Sealed: Yes $\boxed{\text{No}}$ Shoulder Sealed: $\boxed{\text{Yes}}$ No Type: *II(#12)*

Longitudinal Slope *2.9* % Cross Slope *2.5* %

Subgrade Information:

Soil Type *Silty Clay* Depth *16-40 inches*

Unified Classification *CL, CH*

AASHTO Classification *A-6(15), A-7-6(34)*

Collector System Information:

Type: (Circle one) 1. No drains 2. Underdrains 3. X-Drains (Geo-comp)

Distance of instrumented outlet from: Upstream outlet ______

Downstream outlet ______

Special features: *Cut section with clay backfill over limestone bedrock*

Test Section 4 Design Features

Instrumented Section Information

County /District: *Sullivan/Vincennes* Route No: *US-41, SB*

Contract No: (Old) *R-8955* Project No: *F-35(11)*

(New) ______ Max. Grade : *1.312%*

Location: *South of Sullivan/Vigo County Line in Farmersburg*

Station to Station: *212+00 - 222+10* Length: *0.483 Miles*

Year of Construction: *1975* Year of last major activity ______

AADT /Year *16400/1986* %Truck *20*

Design Information

Pavement X-section : 1. Asphalt 2. JPCP/JRCP 3. Asp. Overlay on JPCP/JRCP
(Circle one)

Layer:	Material	Type	Thickness
Overlay			
Surface	*Concrete*	*Jointed Reinf*	*10 1/2"*
Base			
Subbase	*Bit. Stabilized*	*5D*	*4"*
Shoulder	*Bit.Base/Comp. Agg*	*#5/Type P*	*3"/9"*

Joints Sealed: Yes $\boxed{\text{No}}$ Shoulder Sealed: $\boxed{\text{Yes}}$ No Type: *I(#12)*

Longitudinal Slope *0.65* % Cross Slope *1.3* %

Subgrade Information:

Soil Type *Silty Clay* Depth *29-40 inches*

Unified Classification *CL*

AASHTO Classification *A-6(8)*

Collector System Information:

Type: (Circle one) 1. No drains 2. Underdrains 3. X-Drains (Geo-comp)

Distance of instrumented outlet from: Upstream outlet *380 feet*

Downstream outlet *197 feet*

Special features: *Upstream and downstram sections slope towards inst. outlet*

Table 4.6 Test Section 5 Design Features

Instrumented Section Information

County /District: *Laporte/Laporte* Route No: *US-30, WB*

Contract No: (Old) *R-4303* Project No: *F-77(18&20)*

(New) *RS - 17329* Max. Grade : *1.00%*

Location: *Section b/w Wanatah and Hanna*

Station to Station: *560+88 - 879+52* Length: *6.05 Miles*

Year of Construction: *1959* Year of last major activity *1989*

AADT /Year *16770/1987* %Truck *20*

Design Information

Pavement X-section : (Circle one) 1. Asphalt 2. JPCP/JRCP 3 Asp. Overlay on JPCP/JRCP

Layer:	Material	Type	Thickness
Overlay	*Asphalt*	*HAE*	*6"*
Surface	*Concrete*	*Jointed Reinf*	*9"*
Base			
Subbase	*Fine Sand*		*5"*
Shoulder	*Bit.Base/Comp. Agg*	*#5/Type O*	*2"/6"*

Joints Sealed: Yes $\boxed{\text{No}}$ Shoulder Sealed: $\boxed{\text{Yes}}$ No Type: *I(#12)*

Longitudinal Slope *0.2* % Cross Slope *2.4* %

Subgrade Information:

Soil Type *Fine Sand* Depth *24-35 inches*

Unified Classification *SP-SM*

AASHTO Classification *A-3(0)*

Collector System Information:

Type: (Circle one) 1. No drains 2. Underdrains 3. X-Drains (Geo-comp)

Distance of instrumented outlet from: Upstream outlet *500 feet*

Downstream outlet *500 feet*

Special features: *Fill section*

Table 4.7 Test Section 6 Design Features

Instrumented Section Information

County /District: *StJoseph/Laporte* Route No: *US-31, NB*

Contract No: (Old) *R-5464* Project No: *F-720(5)*

(New) *RS - 17563* Max. Grade : *2.52%*

Location: *Section b/w Mayflower Rd. and SR-2 Intterchange on South Bend Bypass*

Station to Station: *115+00 - 210+00* Length: *2.34 Miles*

Year of Construction: *1963* Year of last major activity *1989*

AADT /Year *13080/1987* %Truck *20*

Design Information

Pavement X-section : 1. Asphalt 2. JPCP/JRCP 3 Asp. Overlay on JPCP/JRCP
(Circle one)

Layer:	Material	Type	Thickness
Overlay	*Asphalt*	*HAE*	*3 1/2""*
Surface	*Concrete*	*Jointed Reinf*	*9"*
Base			
Subbase	*Crushed Agg.*	*Type II*	*5"*
Shoulder	*Bit.Base/Comp. Agg*	*#5/Type P*	*3"/5"*

Joints Sealed: Yes $\boxed{\text{No}}$ Shoulder Sealed: $\boxed{\text{Yes}}$ No Type: *I(#12)*

Longitudinal Slope *0.6* % Cross Slope *1.3* %

Subgrade Information:

Soil Type *Poorly graded Sand* Depth *30-54 inches*

Unified Classification *SP*

AASHTO Classification *A-3(0)*

Collector System Information:

Type: (Circle one) 1. No drains 2. Underdrains 3. X-Drains (Geo-comp)

Distance of instrumented outlet from: Upstream outlet *937 feet*

Downstream outlet *937 feet*

Special features: *Upstream outlet distance approximated (location buried)*

Table 4.8 Test Section 7 Design Features

Instrumented Section Information

County /District: *Noble/Ft.Wayne* Route No: *SR-9, NB*

Contract No: (Old) *R-7475* Project No: *S-412(9)*

(New) ______ Max. Grade : *5.83%*

Location: *Section b/w Merriam and Albion (near Chain-o-Lakes State Park)*

Station to Station: *527+83.70 - 953+55* Length: *7.644 Miles*

Year of Construction: *1964* Year of last major activity ______

AADT /Year *3910/1987* %Truck *20*

Design Information

Pavement X-section : (Circle one) 1. Asphalt 2. JPCP/JRCP 3. Asp. Overlay on JPCP/JRCP

Layer:	Material	Type	Thickness
Overlay			
Surface	*Asphalt*	*HAE*	*3 1/2""*
Base	*Asphalt*	*HAE#5*	*6"*
Subbase	*Crushed Gravel*	*Type P*	*6"*
Shoulder	*Bit.Base*	*#53B*	*9" Avg.*

Joints Sealed: Yes **No** Shoulder Sealed: **Yes** No Type: *II(#12)*

Longitudinal Slope *0.12* % Cross Slope *3.0* %

Subgrade Information:

Soil Type *Sand and gravelly sand* Depth *24-40 inches*

Unified Classification *SW*

AASHTO Classification *A-1-a*

Collector System Information:

Type: (Circle one) 1. No drains 2. Underdrains 3. X-Drains (Geo-comp)

Distance of instrumented outlet from: Upstream outlet *600 feet*

Downstream outlet *200 feet*

Special features: *Groundwater present at instrumented site*

Table 4.9 Test Section 8 Design Features

Instrumented Section Information

County /District: *Tippecanoe/Crawfordsville* Route No: *SR-43, NB*

Contract No: (Old) *Force Account* Project No: *M-6262*

(New) *RS-13408* Max. Grade : *0.80%*

Location: *North of West Lafayette; either side of US-52 overpass*

Station to Station: *0+00 - 228+50* Length: *2.62 Miles*

Year of Construction: *1926* Year of last major activity *1985*

AADT /Year *4550/1985* %Truck *10*

Design Information

Pavement X-section : (Circle one) 1. Asphalt 2. JPCP/JRCP 3. Asp. Overlay on JPCP/JRCP

Layer:	Material	Type	Thickness
Overlay			
Surface	*Asphalt*	*HAE*	*5 1/2"*
Base	*Ballast*	*Road Mix*	*6"*
Subbase	*Gravelly Sand*	*Type P*	*5"*
Shoulder	*Crushed Agg.*		*9"*

Joints Sealed: Yes $\boxed{\text{No}}$ Shoulder Sealed: Yes $\boxed{\text{No}}$ Type:_____

Longitudinal Slope *0.8* % Cross Slope *1.2* %

Subgrade Information:

Soil Type *Silty loam* Depth *24-48 inches*

Unified Classification *CL*

AASHTO Classification *A-4(4)*

Collector System Information:

Type: (Circle one) 1. No drains 2. Underdrains 3. X-Drains (Geo-comp)

Distance of instrumented outlet from: Upstream outlet ________

Downstream outlet ________

Special features: *Two lane facility sloping towards Wabash River*

Table 4.10 Test Section 9 Design Features

Instrumented Section Information

County /District: *Vermillion/Crawfordsville* Route No: *SR-63, SB*

Contract No: (Old) *R-10093* Project No: *ST-F-305(22)*

(New) ______ Max. Grade : *3.00%*

Location: *Section b/w US-36 and SR-71 near Newport*

Station to Station: *724+68.00 - 925+24.68* Length: *2.279 Miles*

Year of Construction: *1977* Year of last major activity ______

AADT /Year *7900/1988* %Truck *20*

Design Information

Pavement X-section : (Circle one) 1. Asphalt 2. JPCP/JRCP 3. Asp. Overlay on JPCP/JRCP

Layer:	Material	Type	Thickness
Overlay			
Surface	*Asphalt*	*HAE*	*3"*
Base	*Asphalt*	*HAE#5*	*9 1/2"*
Subbase	*Crushed Agg.*	*#53*	*4 1/2"*
Shoulder	*Bit.Base*	*#53B*	*9" Avg.*

Joints Sealed: Yes No Shoulder Sealed: Yes No Type: *II*

Longitudinal Slope *0.54* % Cross Slope *0.8* %

Subgrade Information:

Soil Type *Gravelly sand* Depth *26-50 inches*

Unified Classification *SW*

AASHTO Classification *A-1-a*

Collector System Information:

Type: (Circle one) 1. No drains 2. Underdrains 3. X-Drains (Geo-comp)

Distance of instrumented outlet from: Upstream outlet *248 feet*

Downstream outlet *352 feet*

Special features: *Special subgrade treatment; inst. section on hilltop*

Table 4.11 Test Section 10 Design Features

Instrumented Section Information

County /District: *Hendricks/Crawfordsville* Route No: *US-36, WB*

Contract No: (Old) *R-13110* Project No: *F-076-2(4)*

(New) ______ Max. Grade : *2.95%*

Location: *From East of Danville to West of SR-267 in Avon*

Station to Station: *46+70 - 356+83.19* Length: *5.263 Miles*

Year of Construction: *1987* Year of last major activity ______

AADT /Year *12530/1987* %Truck *15*

Design Information

Pavement X-section : 1. Asphalt 2. JPCP/JRCP 3. Asp. Overlay on JPCP/JRCP
(Circle one)

Layer:	Material	Type	Thickness
Overlay			
Surface	*Concrete*	*JRCP*	*8 1/2"*
Base			
Subbase	*Bit. Stabilized*	*#53B*	*6 "*
Shoulder	*Bit.Base*	*#5*	*8"*

Joints Sealed: Yes $\boxed{\text{No}}$ Shoulder Sealed: $\boxed{\text{Yes}}$ No Type: *II(#12)*

Longitudinal Slope *0.6* % Cross Slope *1.3* %

Subgrade Information:

Soil Type *Loam* Depth *30-54 inches*

Unified Classification *CL*

AASHTO Classification *A-4(3)*

Collector System Information:

Type: (Circle one) 1. No drains 2. Underdrains 3. X-Drains (Geo-comp)

Distance of instrumented outlet from: Upstream outlet *800 feet*

Downstream outlet *500 feet*

Special features: *Special subgrade treatment at section*

prefabricated edge drains. Also, the main emphasis was tp acquire data for calibration of the computer program PURDRAIN.

The instrumentation package utilized consisted of depth level pressure transducers to measure pressures in terms of hydraulic heads, gypsum blocks to measure availability of moisture in terms of moisture tension in the subbase and subgrade material, a thermistor probe to measure temperature variation within the subbase, a rain gage to measure precipitation, and a tipping bucket outflow measuring device. A battery powered data acquisition system was used to record the data.

Instrumentation was carried out over a period of two years between 1990 and 1991. Initially, a single set of instrumentation package was purchased and used for instrumentation of a pilot test site on US-31, Hamilton County. Subsequently two additional instrumentation packages were purchased. As a result, three sites could be instrumented and data collected at the same time.

Description of Instruments

Data Acquisition System

A Campbell Scientific CR-10 programmable measurement and control module with its supporting software was used to acquire and store data. The control module is compact, rugged and waterproof, and runs on a 12V battery power supply. It can be programmed for different instruments, either through its

keyboard display or through any IBM compatible computer using the software provided with the system. The program consists of a series of instructions designed to perform measurement, data processing, data storage, and logical control functions.

Program development is accomplished either with a prompt sheet and keyboard or through a prompt-driven, computer based datalogger program editor. A program written by USGS (Scott, 1989) was used with modifications for the instruments in this study. The program had to be modified for each site as a result of changes in the calibration constants of various instruments. A sample program is shown in Appendix A.

There are several data retrieval options available with the CR-10 datalogger. In this study, a storage module was used to store and retrieve the data from the site. The storage module is connected to the datalogger at the test site, and can be removed and brought to the laboratory for downloading the data into a personal computer. Figure 4.5 shows the CR-10 control module with its keyboard display and power pack.

Pressure Transducer

A depth/level pressure transducer was used to determine the hydrostatic pressure in pavements. The pressure transducer used is the Druck PDCR831 depth/level type transducer and is shown in Figure 4.6. The operating temperature range of the transducer is -5° to +175° F and the operating pressure range is ±2.5 psi. A hydraulic damper is incorporated in the

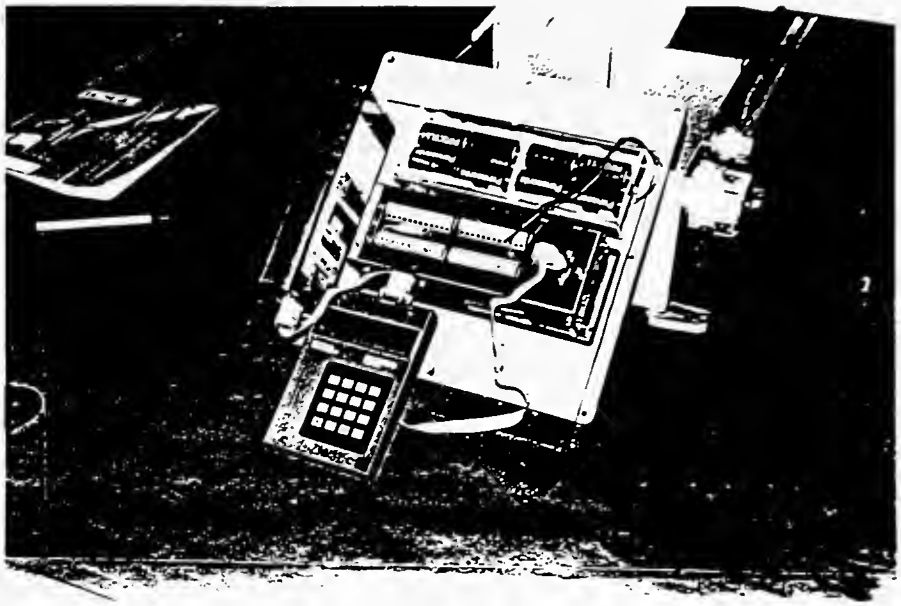


Figure 4.5 View of CR-10 datalogger and component systems

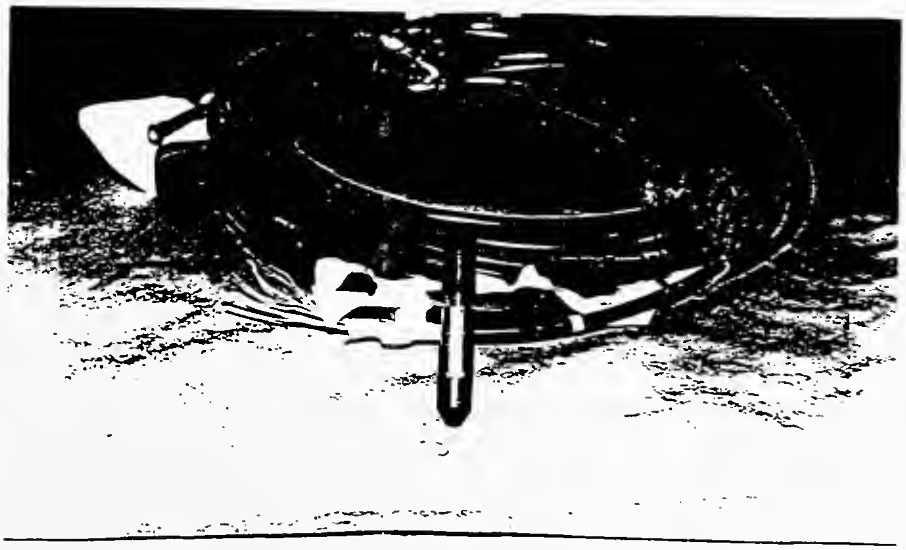


Figure 4.6 Druck PDCR-831 depth/level transducer

transducer to protect the device from high pressure pulses.

Each pressure transducer was calibrated by connecting it to the datalogger. The pressure range, supply voltage and span in mV was noted. Pressure is converted into piezometric head in terms of feet of water and a multiplier value is found by the use of the expression:

$$Multiplier = \frac{pressure(psig)\ x\ conversion\ factor}{span/supply\ voltage}$$

Once the multiplier is determined, it is read into the data acquisition program in the datalogger. Initially the offset representing deviation from zero gage pressure for each transducer value is set to zero in the program. The diaphragm of the transducer is wetted by inserting it into a graduated cylinder filled with water. The transducer is removed from the cylinder after few seconds and the offset value is recorded. The new offset value is then entered into the program instead of the previous zero value.

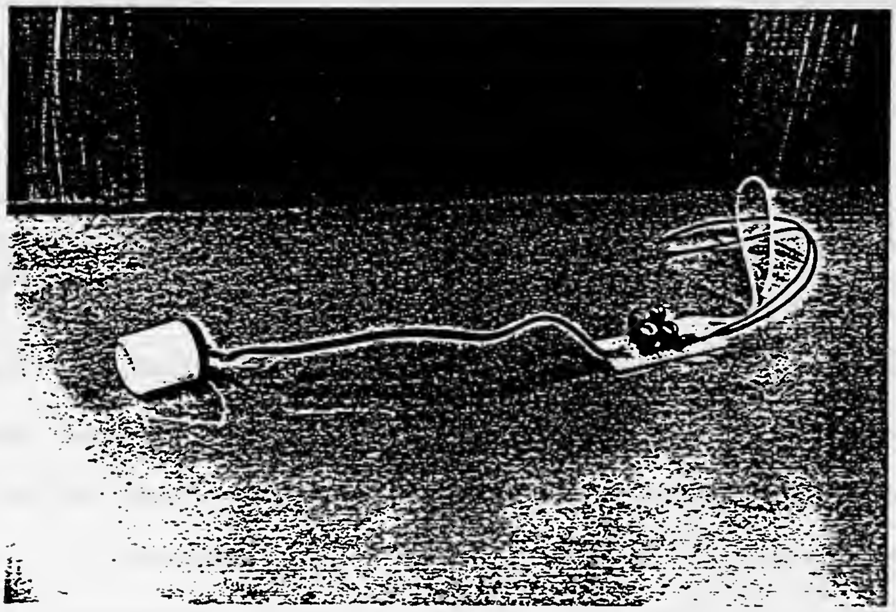
The transducer is again inserted into the graduated cylinder to a certain depth, and the height of water from the tip of the diaphragm to the surface is recorded. The height of water should correspond to the reading displayed on the datalogger keyboard within a small deviation (1/100 th of an inch). The transducer is removed from the cylinder, held in the atmosphere and reading on the datalogger display checked. It should read zero. If not, the transducer vent pipe is checked for blockage, and the procedure repeated.

<u>Gypsum Blocks</u>

Soil moisture blocks were used in this study for estimating soil moisture potential. One inch diameter cylindrical blocks made of gypsum cast around two concentric mesh electrodes were used. This confines current flow to the interior of the block. With time, the pore water pressure in the gypsum reaches equilibrium with the soil surrounding it. The determination of moisture is made by relating the change in moisture tension to change in resistance of the block. The gypsum blocks are manufactured by Delmhorst and were modified for the pilot test section by adding four tantalum 100 mfd capacitors and a 1 Kohm metal film resistor to block galvanic action due to the differences in potential between the datalogger earth ground and electrodes in the block. Without it, there would have been rapid block deterioration. The block and its circuit diagram is shown in Figure 4.7. These modifications were also necessary because of configuration requirements with the datalogger system. Blocks for the remaining sections were factory modified to be compatible with the datalogger program.

Soil moisture potential is predicted by utilizing a 5th order polynomial processing instruction supplied by the datalogger manufacturer. The datalogger outputs sensor resistance which is converted to moisture potential using the polynomial coefficients listed in Table 4.12.

Conditioning of the gypsum block unit was done by first



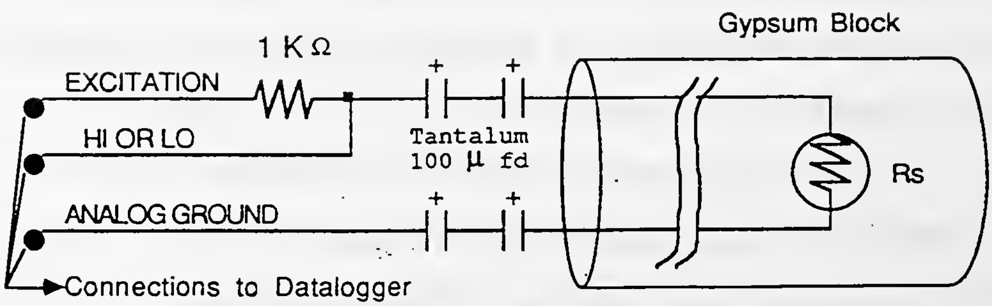


Figure 4.7 Modified gypsum block and circuit diagram

Table 4.12 Polynomial Coefficients for Converting Sensor Resistance to Bars and Resulting Polynomial Error (Campbell Scientific, Inc.)

$$BARS = C_0 + C_1(R_S) + C_2(R_S)^2 + C_3(R_S)^3 + C_4(R_S)^4 + C_5(R_S)^5$$

(BARS)	MULT. (R_1)	C_0	C_1	C_2	C_3	C_4	C_5
0.1-10	0.1	.15836	6.1445	-8.4189	9.2493	-3.1685	.33392
0.1-2	1.0	.06516	.95117	-.25159	-.03736	.03273	-.00394

Polynomial Error - 2 Bar Range

BARS	V_S/V_X	R_S	BARS COMPUTED	ERROR
0.1	0.0566	0.06	0.1213	0.0213
0.2	0.115	0.13	0.1845	-0.0155
0.3	0.2063	0.26	0.2949	-0.0051
0.4	0.2701	0.37	0.3813	-0.0187
0.5	0.3506	0.54	0.5021	0.0021
0.6	0.4286	0.75	0.6307	0.0307
0.7	0.4624	0.86	0.6894	-0.0106
0.8	0.5238	1.1	0.7989	-0.0011
0.9	0.5833	1.4	0.9057	0.0057
1.0	0.6296	1.7	0.9889	-0.0111
1.5	0.7727	3.4	1.506	0.006
1.8	0.8	4.0	1.7977	-0.0023
2.0	0.8333	5.0	2.005	0.005

Polynomial Error - 10 Bar Range

BARS	V_S/V_X	R_S	BARS COMPUTED	ERROR
0.1	0.0566	0.006	0.1949	0.0949
0.2	0.115	0.013	0.2368	0.0368
0.3	0.2063	0.026	0.3126	0.0126
0.4	0.2701	0.037	0.3746	-0.0254
0.5	0.3506	0.054	0.4670	-0.0330
0.6	0.4286	0.075	0.5756	-0.0244
0.7	0.4624	0.086	0.6302	-0.0698
0.8	0.5238	0.11	0.7442	-0.0558
0.9	0.5833	0.14	0.8778	-0.0222
1.0	0.6296	0.17	1.0025	0.0025
1.5	0.7727	0.34	1.5970	0.0970
1.8	0.8000	0.40	1.7834	-0.0166
2	0.8333	0.50	2.0945	0.0945
3	0.8780	0.72	2.8834	-0.1166
6	0.9259	1.25	6.0329	0.0329
10	0.9444	1.70	9.9928	-0.0072

NOTE: ERROR (BARS) = ACTUAL - COMPUTED

letting the unit go through two cycles of wetting and drying. Each cycle consisted of soaking the gypsum block in water for one hour and then air drying it. This ensures block uniformity.

Temperature Probe

Variation in the subbase temperature was measured with a thermistor. Either a thermistor or a thermocouple would have given the same results. However, the thermocouple requires a reference thermocouple and would use two analog input terminal strips of the datalogger wiring panel. A thermistor probe makes a single ended measurement, and only one terminal strip is required.

Rain Gage

Precipitation was measured with a dual-chamber tipping bucket rain gage manufactured by Texas Instruments, shown in Figure 4.8. Rainfall at rates up to 2 inches per hour can be measured with an accuracy of ±1%. The bucket empties with each 0.01 inch of rainfall, and a signal is transmitted to the datalogger which is programmed to record the number of tips and convert it to inches of rainfall. A time base allows the duration of precipitation to be determined. The raingage was factory calibrated.

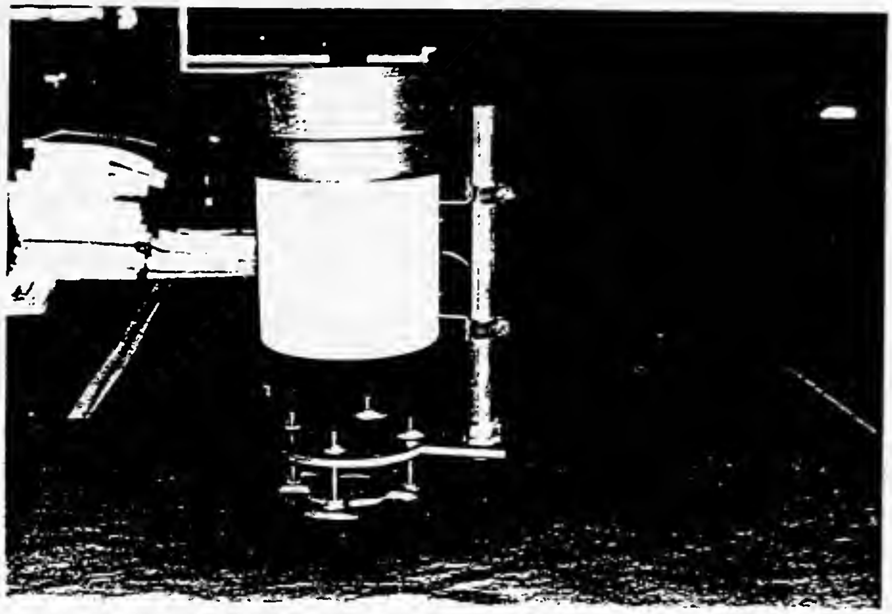


Figure 4.8 View of rain gage

Outflow Measuring Device

Edge drain outflow was also measured with a dual chamber tipping bucket device, shown in Figure 4.9. The tipping bucket works the same way as the raingage. Specifications for the outflow measuring device were obtained from the Wisconsin DOT. However, some modifications were incorporated prior to its fabrication by the Purdue University Central Machine Shop. Rubber pads were added at the base of the bucket to absorb impact when chambers tilt. Also the top portion of the bucket was modified to stop water spilling over the sides.

A laboratory calibration check was made of each outflow device prior to field use. Water was introduced into the chamber and the volume of water for each tip was recorded. Three readings were made for each chamber and the average value for both chambers was programmed into the datalogger. A list of the instruments and support systems and their respective costs are attached as Appendix B.

Instrumentation Setup

Pavement instrumentation was carried out with the assistance of the Indiana Department of Transportation personnel. A schematic of the instrumentation layout is shown in Figure 4.10. For the pilot test site on US-31, Hamilton County, four inch diameter cores for pressure transducers and two inch diameter cores for moisture blocks were removed from the pavement to the subbase and shoulder base levels. These

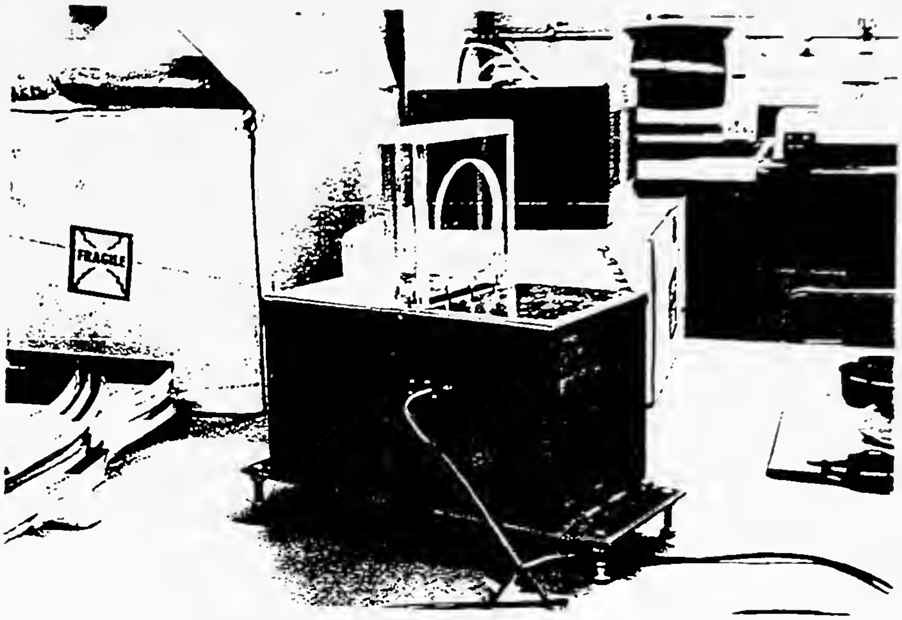


Figure 4.9 View of outflow measuring device

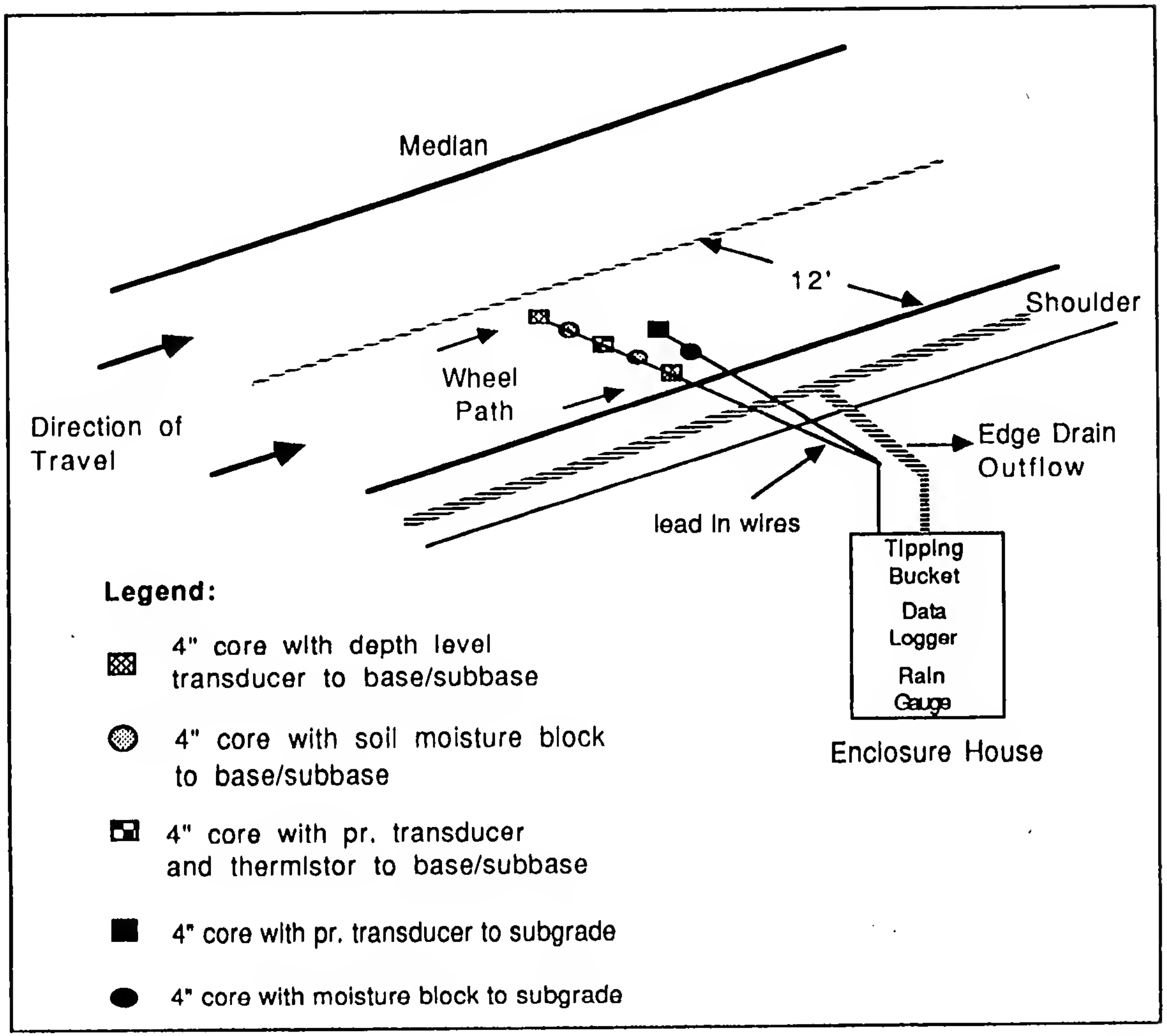


Figure 4.10 Schematic of instrumentation layout at test sites

holes were connected through a sawcut in the pavement and shoulder, so that lead wires from various instruments could be routed to the edge of the pavement and eventually to the datalogger (Figure 4.11).

Two changes were made in coring the remaining test sections. Four-inch diameter cores were also drilled for the moisture blocks to counter difficulty of removing the two-inch cores and placing the gypsum blocks. To obtain a better profile of moisture variation beneath the pavement, it was decided to place a transducer and moisture block at the subgrade level. Limitations of the datalogger channels precluded the use of additional sensors. As data from the pilot test site did not indicate a pronounced moisture change in the shoulder section, sensors from the shoulders were transferred to the pavement subgrade for the remaining nine test sections.

Pressure transducers were inserted into the 4 inch diameter holes as shown in Figure 4.12. Each transducer was wrapped with a permeable geofabric to shield the sensor diaphragm from soil contamination. The transducers were placed vertically in the holes which were backfilled with pea gravel. Care was taken to ensure that all the pressure transducers were at the same depth in the subbase. A temperature probe was placed along with the second pressure transducer.

The gypsum blocks were conditioned prior to placement by packing them in excavated subbase material. They were then

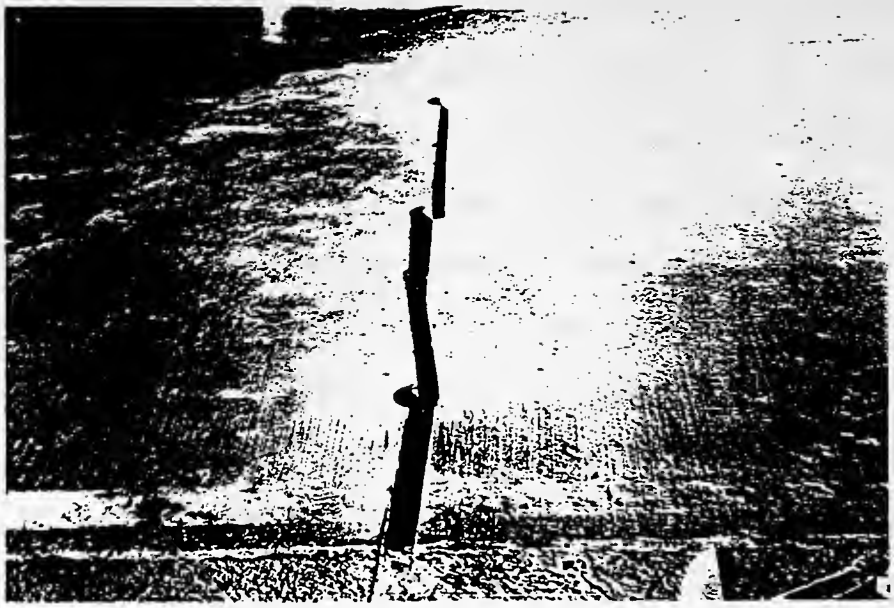


Figure 4.11 Sawcut in pavement for routing wires to datalogger

Figure 4.12 Depth/level transducer installation in core hole

allowed to saturate by placing them along with the packing material in a pan of water for 10 minutes. While still encased in the subbase material, the blocks were inserted into the cored holes which were then backfilled with excavated material. To cover the exposed sensor cables in the sawcut, first a cylindrical joint backer rod was placed in the cut which was then backfilled with asphalt mix. At some sites, use was made of asphalt felt for covering the sensor cables. For transducers and blocks placed at the subgrade level, the cores were sealed at the subgrade/subbase interface with a slurry of bentonite clay. The purpose of this step was to prevent water from infiltrating from the subbase, which otherwise would have resulted in a biased reading for the transducers and moisture blocks.

A custom built enclosure to house the datalogger, precipitation gage and outflow tipping bucket was fixed to a concrete pad on the embankment slope of each instrumented section (Figure 4.13). Lead wires from the instruments were run through the saw cuts and a trench in the embankment to the enclosure housing the datalogger. The datalogger control module, storage module and battery power pack were housed in a plastic box inside the enclosure.

The raingages were placed in the upper portion of the enclosure with their top open to the atmosphere. The outflow tipping buckets were placed in the lower portion of the enclosure and connected to the underdrain outlet pipe by means

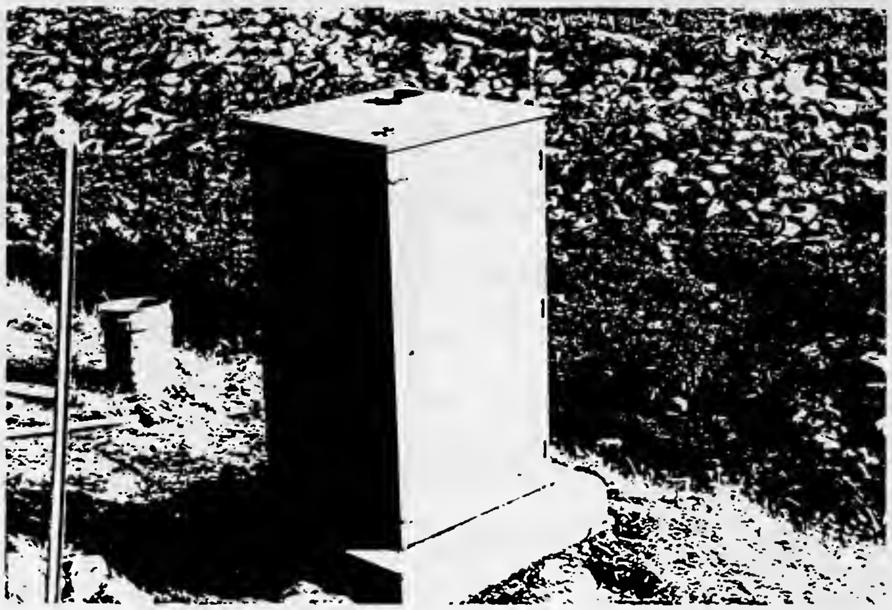


Figure 4.13 Enclosure housing the monitoring instruments

of a connecting pipe and boot (Figure 4.14). Lead wires from the instruments were connected to the CR-10 wiring panel terminals. The connection diagram is shown in Table 4.13.

Subgrade soil samples were collected from test sites through auger borings, shelby tubes and split spoon samplers using a hydraulic coring rig (Figure 4.15). These samples were brought to Purdue University for determination of various soil properties as described in Chapter 5.

The instruments were left at each site for a period of two to three months to record at least one major precipitation event. Subsequently, the instruments were removed for installation at the next site. Prior to reinstallation, depth level transducers, raingage and outflow tipping bucket were checked and re-calibrated. A new set of moisture blocks were used for each site.

Programming and Data Retrieval

The data collection program was loaded through the datalogger keyboard. A variable sampling rate was used. For a rainfall event, data was recorded at five minute intervals, with cumulative values being recorded on fifteen minutes, hourly and daily basis. Data from other instruments were based on average values for the above time periods. In the absence of rainfall and flow, data is recorded on a daily basis to save battery power.

Data was retrieved on a monthly basis by disconnecting

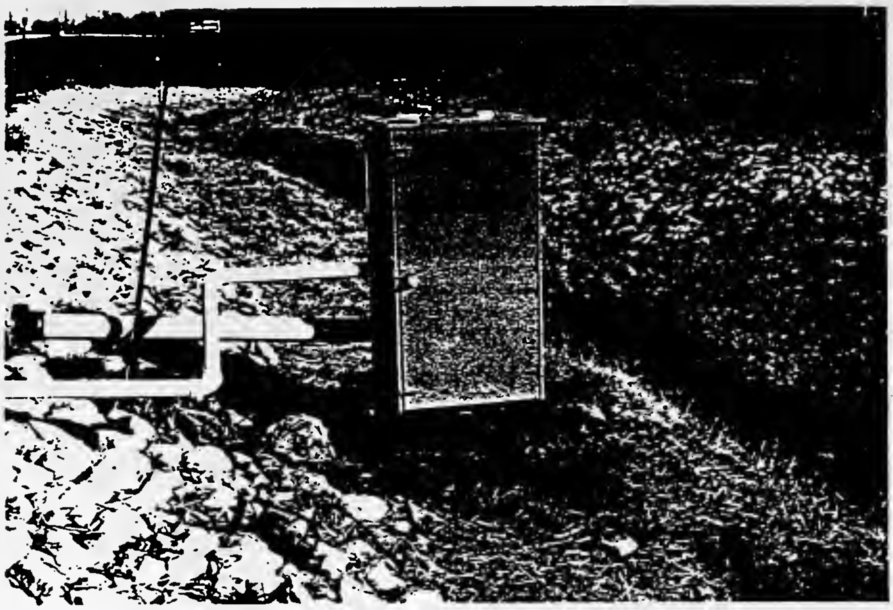


Figure 4.14 Connections for outlet pipe and lead wires

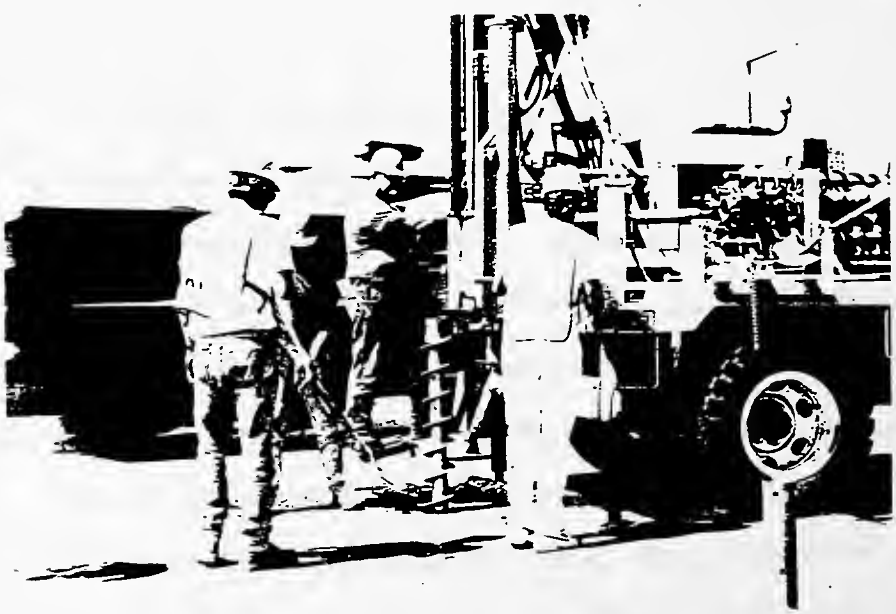


Figure 4.15 Auger boring for soil sample collection

Table 4.13 Wiring Connection for CR-10 Datalogger

1H	Druck # 1 Pos signal (yellow)	Druck # 4 Pos signal (yellow)	4H
1L	Druck # 1 Neg signal (blue)	Druck # 4 Neg signal (blue)	4L
2H	Druck # 2 Pos signal (yellow)	Delmhorst # 1 Signal (red)	5H
2L	Druck # 2 Neg signal (blue)	Delmhorst # 2 Signal (red)	5L
3H	Druck # 3 Pos signal (yellow)	Delmhorst # 3 Signal (red)	6H
3L	Druck # 3 Neg signal (blue)	Temperature Signal (red)	6L
AG			AG
AG	Delmhorst Ground (bare wire)	Temperature Excitation (black)	E3
E2	Delmhorst Excitation (3 black)	Temperature Ground	AG
E1	Druck Excitation (4 red)		AG
AG	Druck Ground (4 white)		AG
AG			AG
P1	Rain tipping bucket (red)	Druck Shield (2 bare wires)	G
P2	Flow tipping bucket (red)	Druck Shield (2 bare wires)	G
C8		Tipping bucket Ground (2 black)	G
C7			G
C6			G
C5			G
C4			G
C3			G
C2		Power Ground (black)	G
C1		Power Positive (red)	12V
5V			12V
5V			12V

the storage module and transporting it to Purdue University for downloading to a computer. A fresh storage device was left in the field so that data collection was uninterrupted. The datalogger has adequate internal memory storage capacity, such that data is not lost while the storage module is being replaced. For sections with continuous outflow from the drainage system, data retrieval was done on a bi-weekly basis.

Data acquired from instrumented sites was reduced through a software program supplied by Campbell Scientific and analyzed immediately to observe any suspect or missing data. This helped in identifying problems of instrument malfunction described in the following section.

Instrumentation Problems

A number of problems were encountered at various sites because of instrument malfunction, field conditions and human errors.

At some sites, flow tipping buckets stopped working a few days after installation. Inspections revealed microswitch problems, jamming of the lever on which bucket chambers were mounted, stones from punctured pipes blocking water from flowing into the chambers and rodents chewing away cables. At the SR-37, Hamilton County site, installation conditions resulted in reverse flow of water into the bucket immediately after a rainfall event. These problems resulted in missing data for outflow on some sections, which could only be

detected during data reduction. Actions were subsequently taken to rectify these problems with mixed results.

Problems with depth level transducers were primarily due to punctured lead wires. The wires were covered with roofing felt and asphalt mix in sawcuts, but stresses due to vehicle loads resulted in small cuts in the wires. The cuts could not be detected during recalibration, as only the depth end cone of transducers was immersed in water and values of constants checked. After reinstallation at the next site, water penetrated through the cuts and damaged the sensing element in the transducers which resulted in erratic data. At some sites, cuts in the lead wires were the result of improper removal methods for the sensors. The damaged transducers in these cases were shipped to the manufacturer for repairs, but without any success. Due to time and cost constraints, additional transducers were not purchased and at some sites data was obtained from a reduced number of sensors.

The use of fresh moisture blocks for each site avoided the problems of lead wire cuts. Instead, difficulty in achieving full contact between the block and the surrounding soil, especially for stabilized subbases resulted in erroneous data. In addition, saline and acidic soils degraded the blocks within one month at some sites. At some site only the block electrodes remained.

Field Surveys

Field surveys of instrumented sites were conducted to ascertain the profile of the section and to quantify the condition of pavement distress.

Profile Survey

Profiles of the instrumented sections helped in determining longitudinal and cross slopes of the road section. The method of differential leveling was used to determine differences in elevation between selected points on the pavement surface. An automatic level and a graduated measuring rod was used for this purpose. The level was set up at a short distance away from the instrumented outlet. Elevations of the surface at cored points were taken to determine the cross slope of pavement sections. Elevations of three additional points 200 feet upstream and downstream of the instrumented section were also recorded to determine the longitudinal slope of pavement at the instrumented site. An odometer was used for measuring the distance between selected elevation points. A schematic of the leveling plan is shown in Figure 4.16.

Visual Survey

Concurrently with field instrumentation, condition surveys were performed on each pavement section. These surveys determined the extent and severity of pavement surface distresses and pavement-shoulder joint conditions. The PAVER

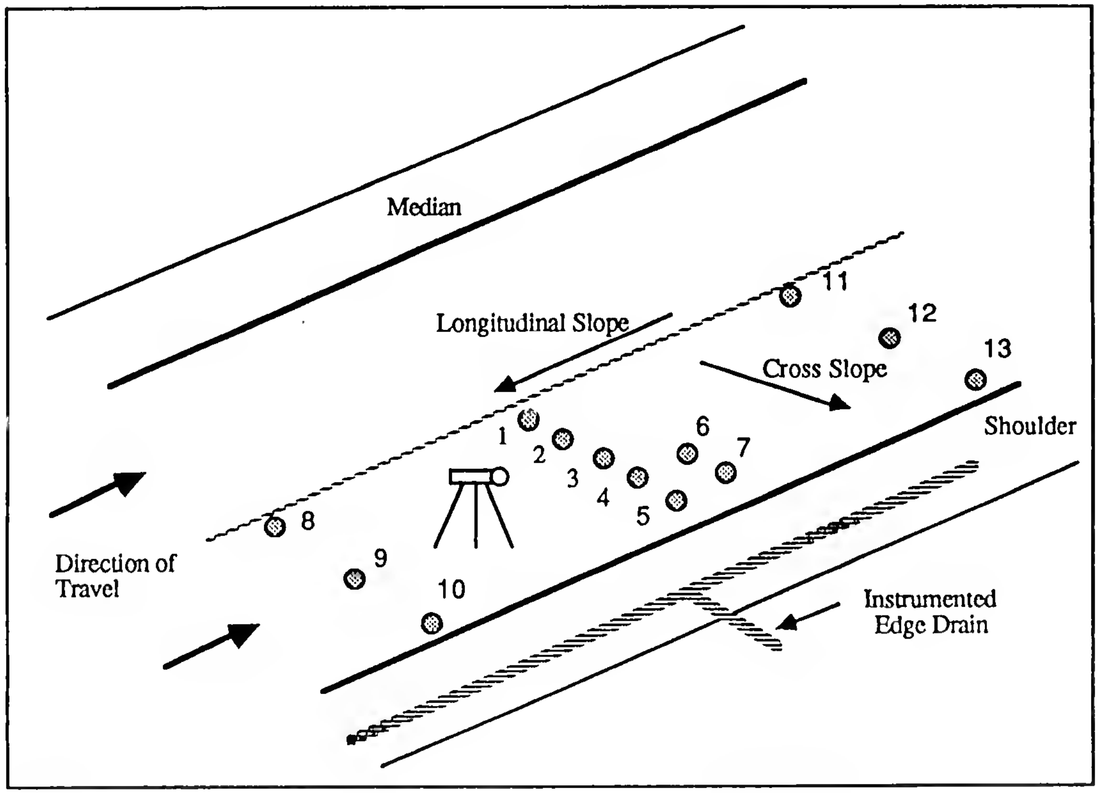


Figure 4.16 Profile levelling plan for instrumented sites

(Shahin and Kohn, 1981) condition survey method was used with minor adjustments. The purpose of inspection was to identify moisture related distresses and pavement-shoulder joint conditions around the instrumented area. Therefore, instead of conducting a condition survey of the entire section, a sectional length of 500 feet on either side of the instrumented area was surveyed. This sample unit length was applied for both flexible and rigid pavements and provided data on the number and location of cracks between two consecutive outlets. This information was needed for calibration of the PURDRAIN program.

Table 4.14 gives a summary of the Pavement Condition Index (PCI) values and ratings for target sections surveyed. Completed inspection sheets are attached as Appendix C.

Chapter Summary

The process of field instrumentation and surveys carried out as part of this research project were described in this chapter. The nature and magnitude of the experimental program conducted for the first time in Indiana, imparted considerable experience in the use of various equipment and installation procedures. Data from some sites were lost due to instrument malfunctioning and field conditions. However, significant data was collected and will aid in calibrating the PURDRAIN program and in analyzing the pattern of moisture changes in the pavement systems from precipitation.

Table 4.14 PCI Values and Ratings for Instrumented Sections

SECTION NUMBER	ROUTE/ COUNTY	PCI (Average)	RATING (Average)
1	US-31 HAMILTON	71.1	V.GOOD
2	SR-37 HAMILTON	75.4	V.GOOD
3	SR-37 LAWRENCE	86.9	EXCELLENT
4	US-41 SULLIVAN	79.2	V.GOOD
5	US-30 LAPORTE	86.3	EXCELLENT
6	US-31 ST.JOSEPH	77.0	V.GOOD
7	SR-9 NOBLE	94.6	EXCELLENT
8	SR-43 TIPPECANOE	73.8	V.GOOD
9	SR-63 VERMILLION	36.8	POOR
10	US-36 HENDRICKS	96.6	EXCELLENT

CHAPTER 5 - LABORATORY INVESTIGATIONS

Background

Laboratory testing in this study was undertaken to determine the soil-moisture characteristics and saturated hydraulic conductivities of subbase materials and subgrade soils present at the instrumented sites. The specific objective to be achieved was to provide information on soil properties to be used in the PURDRAIN program. This chapter describes test methods used in the course of laboratory investigations.

There were three tasks associated with the laboratory testing. The first task involved classification of subbase materials and subgrade soils through conventional material tests. A number of conventional and non-conventional methods were used in this step, described later in this chapter. The second task consisted of testing each classified soil to determine the suction-moisture relationship and hydraulic conductivity. Finally, index parameters were determined for Brooks and Corey's and Van Genuchten's models. This was achieved using laboratory data and iterative procedures described later.

Conventional Material Tests

Tests performed included density and moisture content, grain size distribution, Atterberg limits and specific gravity. Standard ASTM or AASHTO methods were employed except for density measurements, where a non-conventional method was used to determine in-situ density of subgrade samples. A minimum of three replicate samples were prepared for each test.

Density and Moisture Content

Because the pavements included in the study were in service, standard methods such as sand cone tests or nuclear gages could not be used to determine in-situ density of subgrade soils. Shelby tube samples of subgrade soils were therefore collected from each site and brought to the laboratory for density measurements. The samples were stored in a controlled temperature and humidity chamber to minimize moisture loss prior to testing.

The samples while still in the tubes were cut at measured points with a mechanical saw as shown in Figure 5.1. The diameter of the cut samples was measured at two to three points and an average was determined. The length and weight of the samples were also recorded. Subtracting the weight of hollow tube from the overall weight of sample and tube provided data for determining in-situ density.

Moisture contents were determined by ASTM Method D-2216.

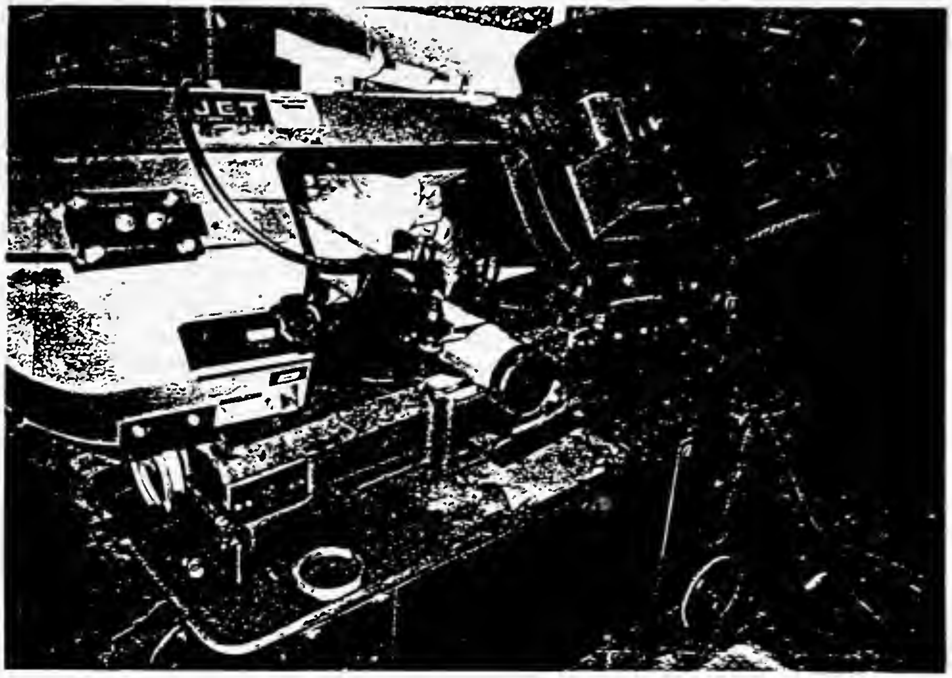


Figure 5.1 Cutting shelby tube with mechanical saw

Grain Size Distribution

Particle size analysis was performed on subgrade samples according to the ASTM Method D-422. Soil aggregate samples were prepared by the method prescribed in the AASHTO T-87. Washed sieve analysis of fine grained and cohesive soils were carried out using ASTM C-117. Sieve analysis was also performed on #5D bituminous stabilized and #53 crushed aggregate samples recovered from the sites. These are the predominant subbase materials used in Indiana.

Atterberg Limits

Atterberg limits of subgrade soils were determined using ASTM Method D-4318. Soil samples were prepared using demineralized water and allowed to stand 16 hours prior to testing. Liquid limit, plastic limit and plasticity index values were determined for each subgrade soil.

Specific Gravity

Specific gravities of soil samples were determined using two methods. AASHTO T-100 was used for fine grained soils. For samples composed of particles larger and smaller than the #4 (4.75mm) sieve size, apparent specific gravity of coarse particles was determined using AASHTO Method T-85. A weighted average specific gravity was then calculated using the following equation:

$$G_{avg}=\frac{1}{\frac{R_1}{100G_1}+\frac{P_1}{100G_2}} \qquad 5.1$$

where:
G_{avg} = weighted average specific gravity of soils
R_1 = percent of soil particles retained on #4 sieve
P_1 = percent of soil particles passing #4 sieve
G_1 = apparent specific gravity of soil particles retained on #4 sieve
G_2 = specific gravity of soil particles passing #4 sieve

Samples of clay soils for specific gravity measurements were prepared using the dispersing equipment specified in AASHTO T-88. Entrapped air was removed by boiling and then subjecting the contents to vacuum.

Test Results

The results of various laboratory tests on the subbase and subgrade soils are presented in Appendix D and include a sample description and soil properties for each of the soils tested. Graphical presentation of gradation analysis are shown in Figures 5.2 to 5.13. Subgrade soils were classified using the Unified Classification Method (ASTM D2487) and the AASHTO Method (AASHTO M-145). Table 5.1 lists the resulting classification by both methods.

Gradation of #5D bituminous stabilized subbase and #53 crushed aggregate subbase materials were compared with specification limits provided by the Indiana Department of Transportation. The stabilized subbase satisfied the gradation and binder specification ranges. Gradations of crushed aggregate samples obtained from two sites fell outside the

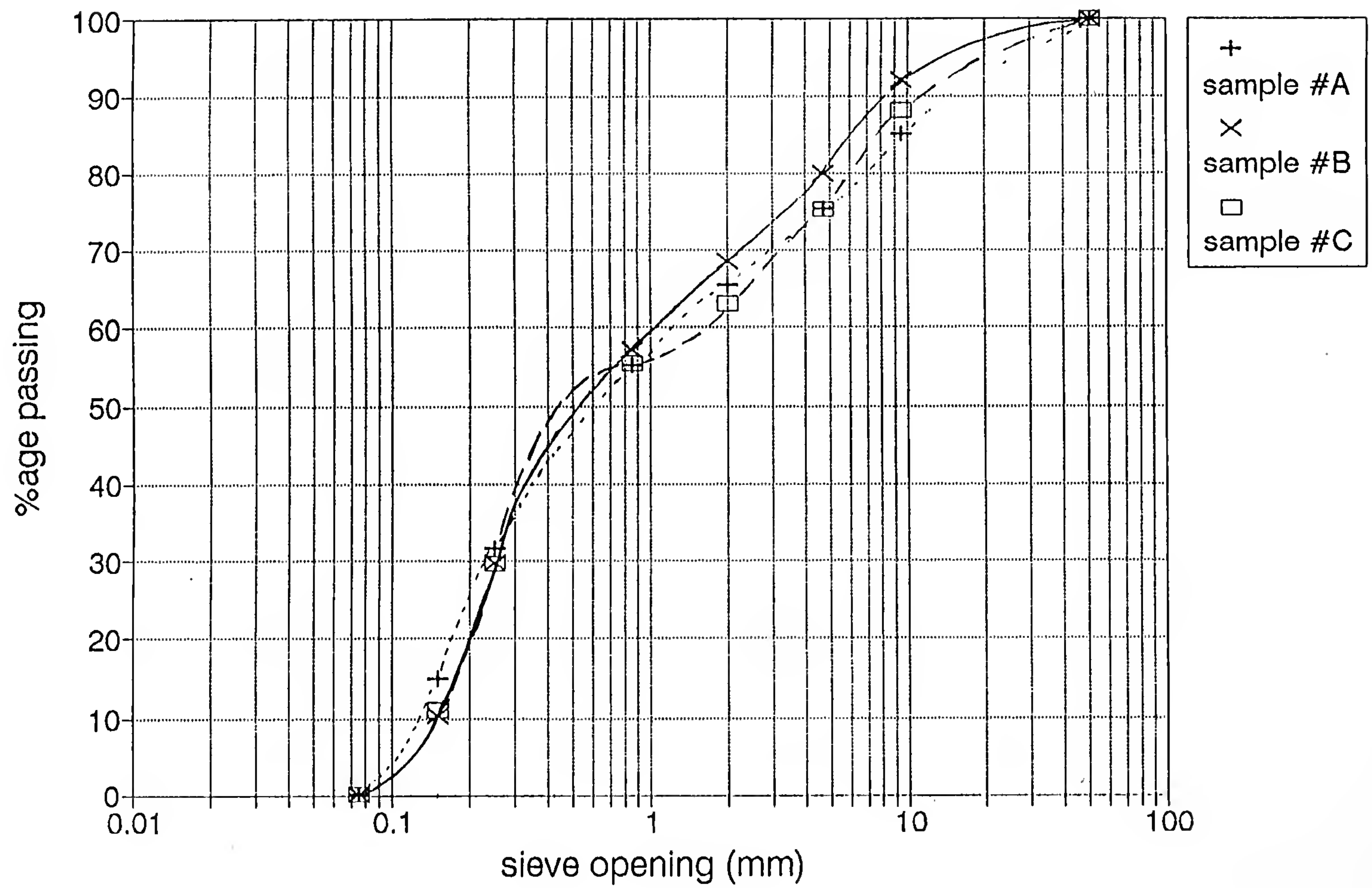


Figure 5.2 As-sampled gradation of US-31, Hamilton County soil

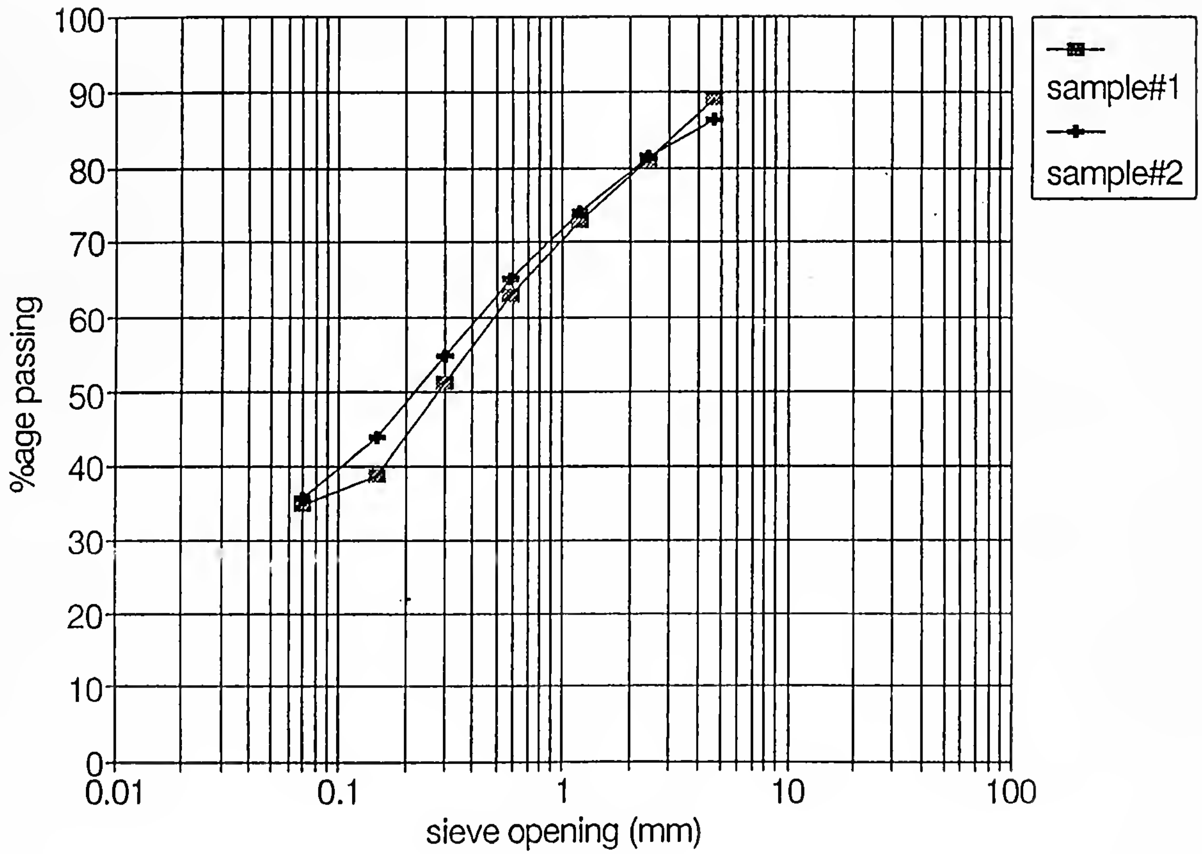


Figure 5.3 As-sampled gradation of SR-37, Hamilton County soil

Gradation curve not displayed for fat clayey soil (>50% pass #200)

Figure 5.4 As-sampled gradation of SR-37, Lawrence County soil

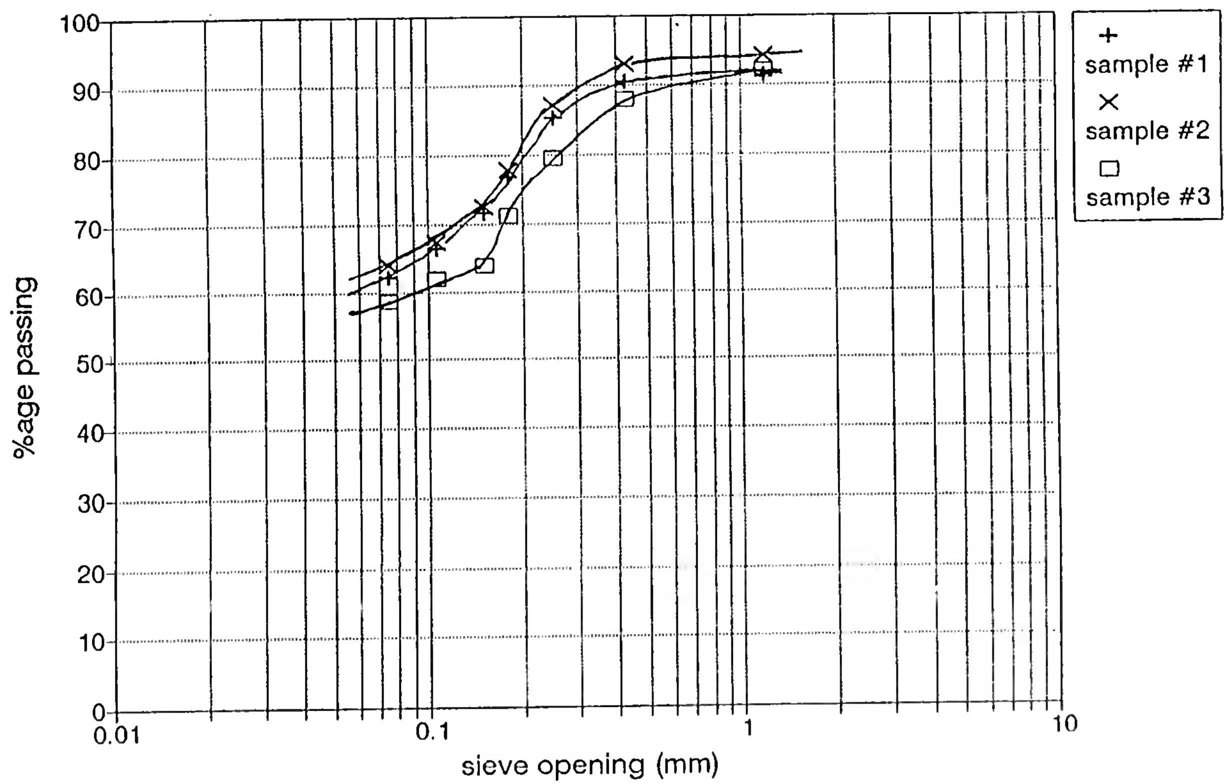


Figure 5.5 As-sampled gradation of US-41, Sullivan County soil

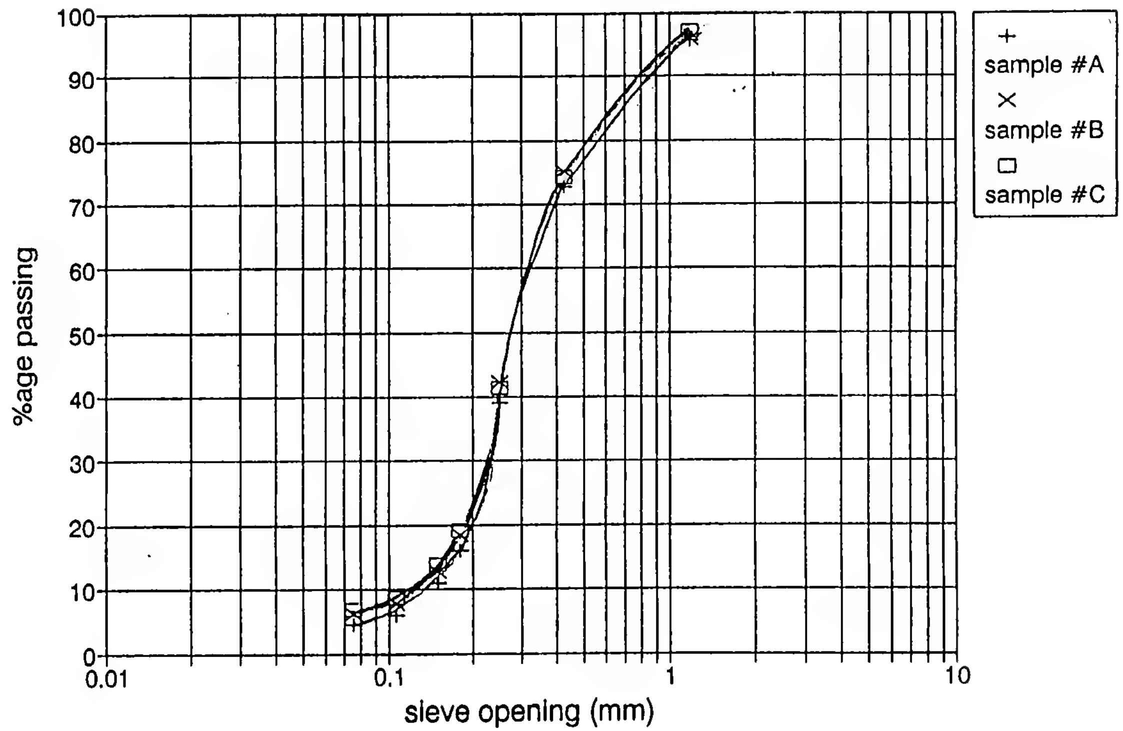


Figure 5.6 As-sampled gradation of US-30, Laporte County soil

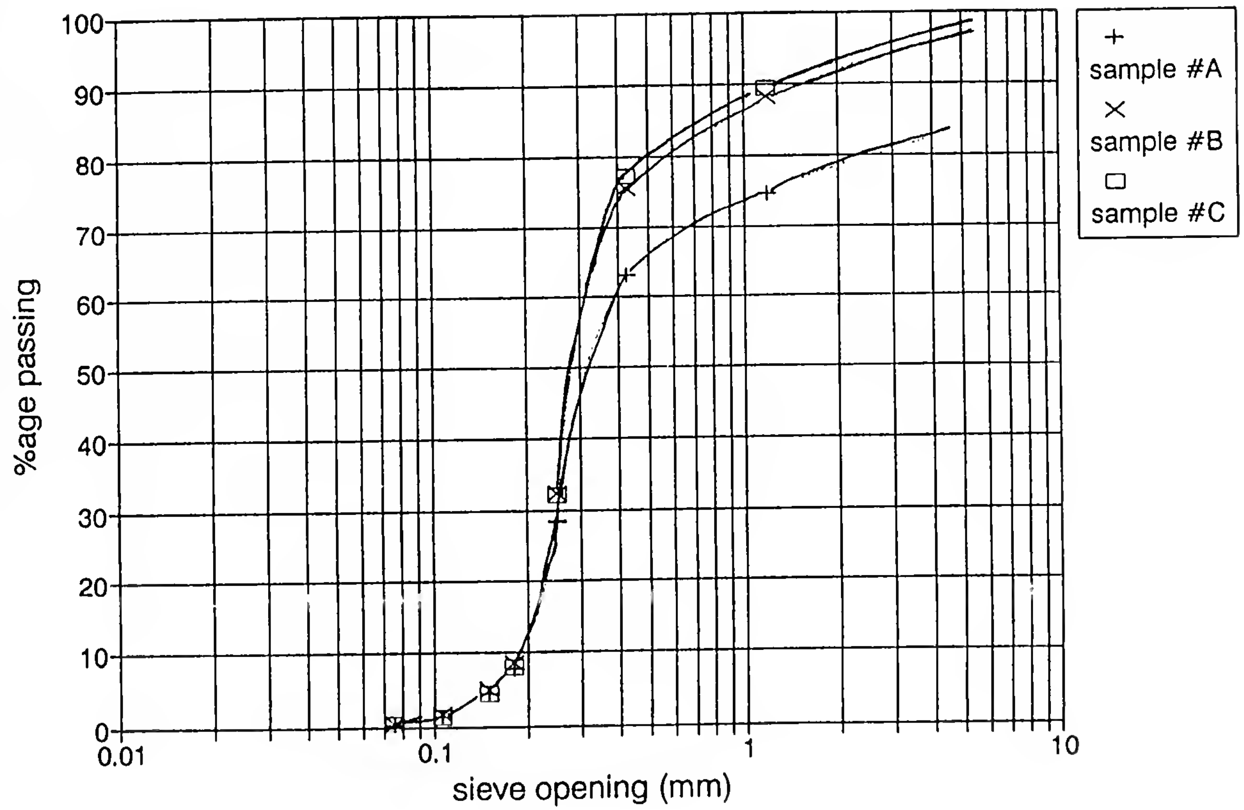


Figure 5.7 As-sampled gradation of US-31, St.Joseph County soil

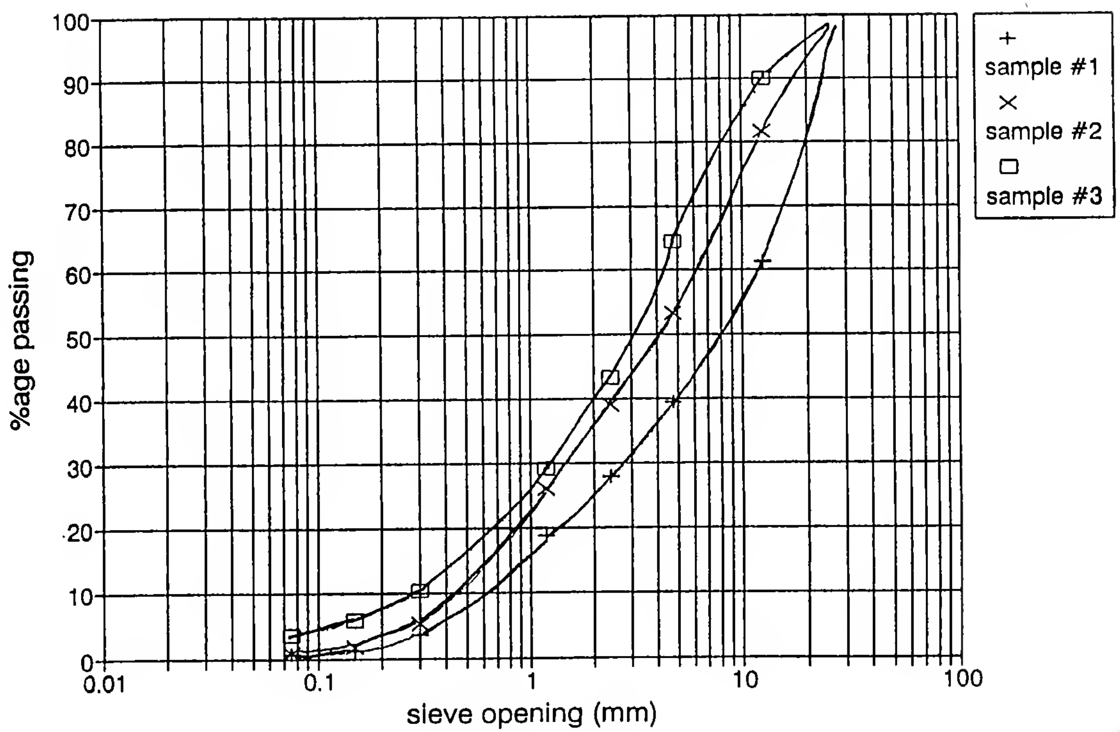


Figure 5.8 As-sampled gradation of SR-9, Noble County soil

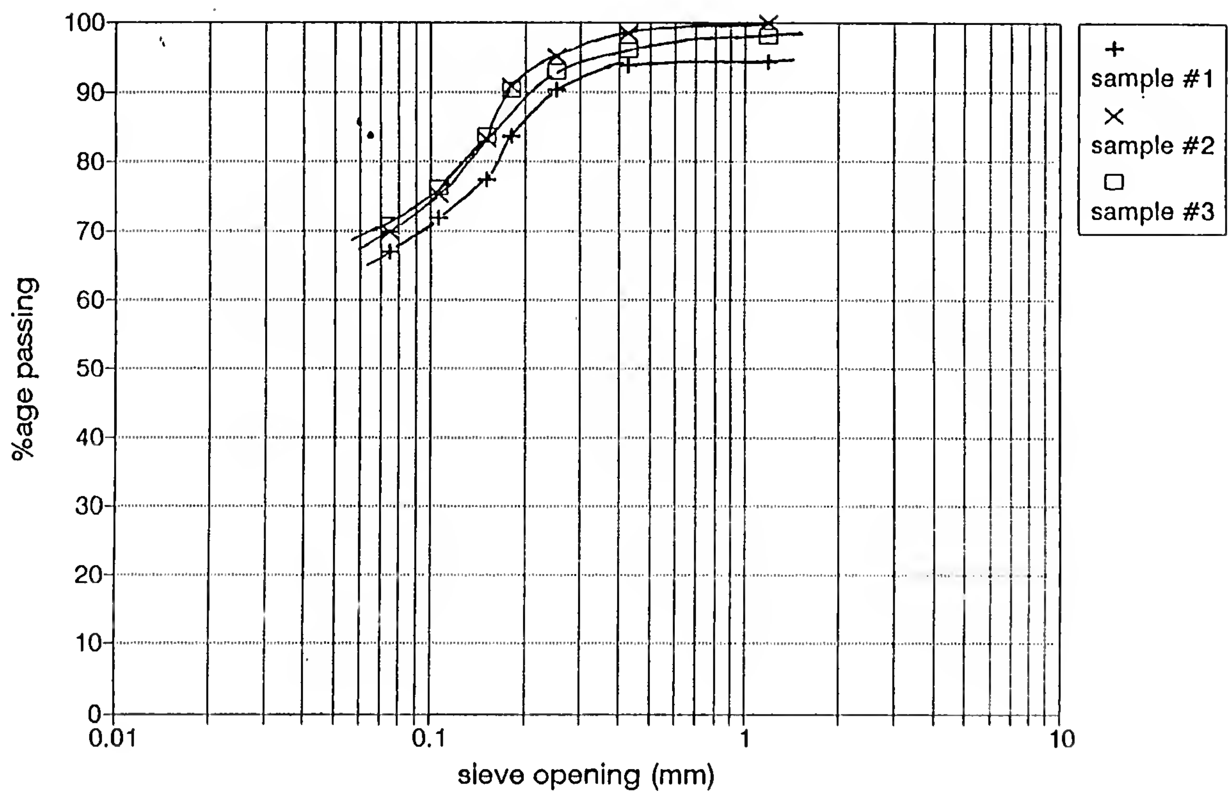


Figure 5.9 As-sampled gradation of SR-43, Tippecanoe County soil

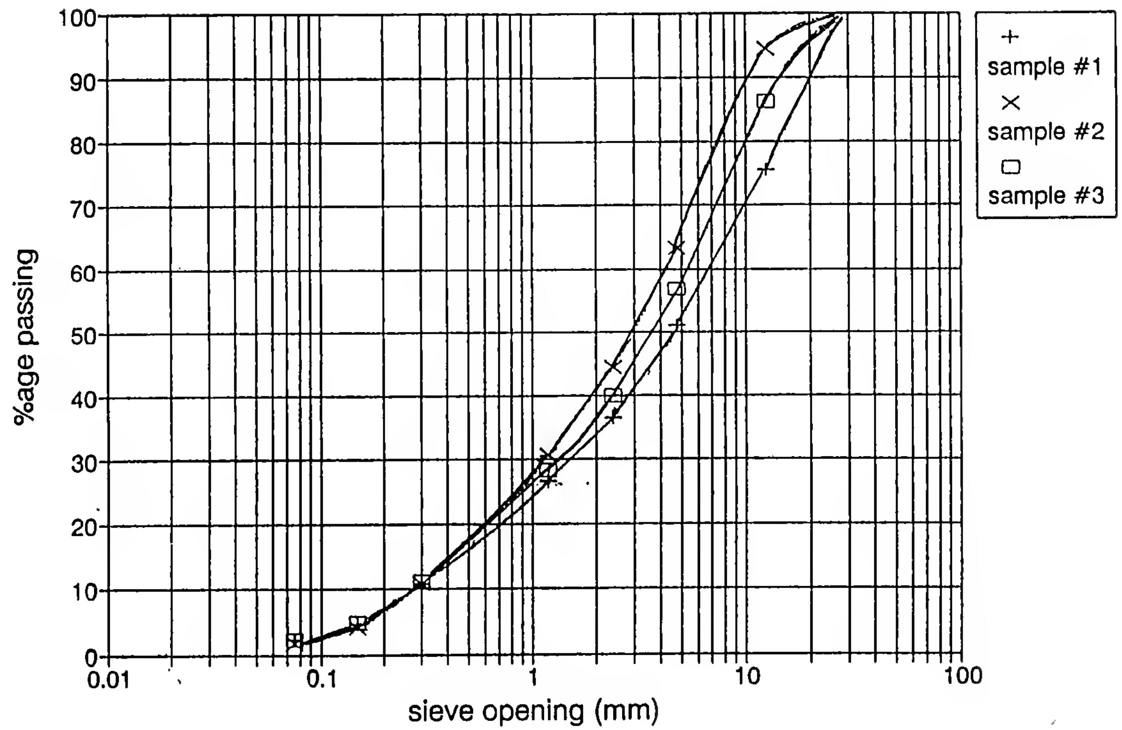


Figure 5.10 As-sampled gradation of SR-63, Vermillion County soil

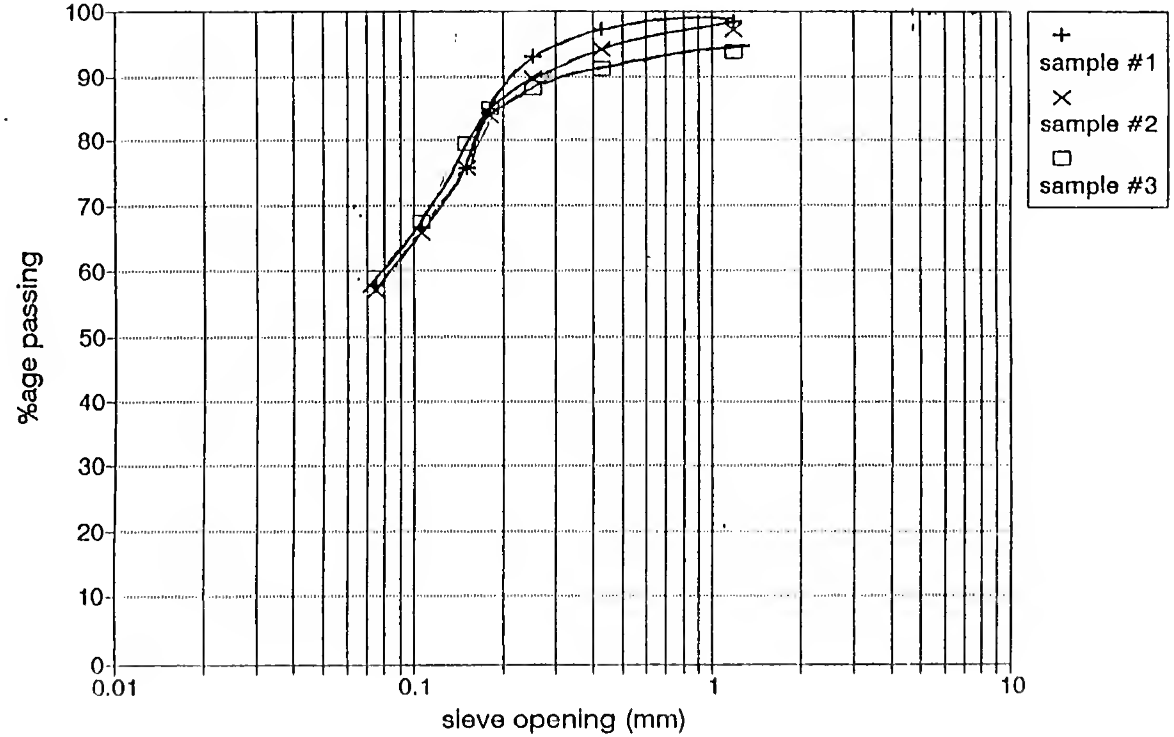


Figure 5.11 As-sampled gradation of US-36, Hendricks County soil

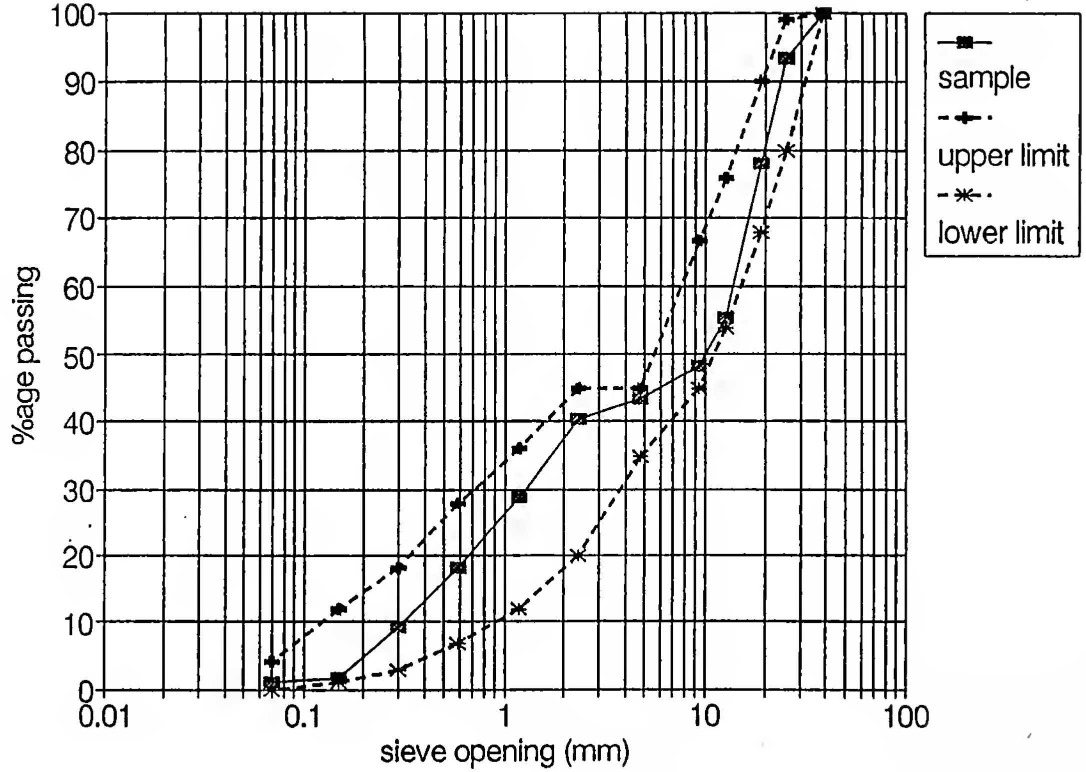


Figure 5.12 Gradation and specification limit for #5D stabilized subbase

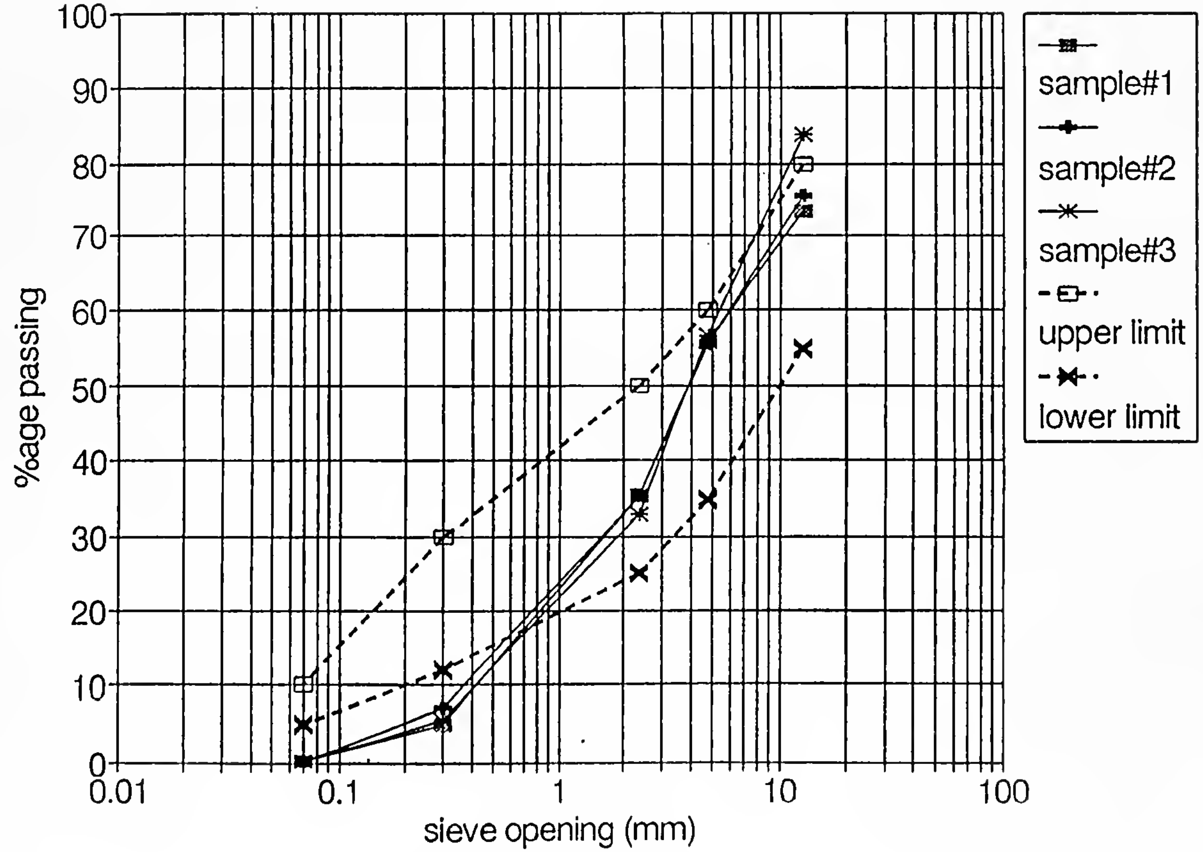


Figure 5.13 Gradation and specification limit for #53 aggregate subbase

Table 5.1 Classification of subgrade soil samples

Section Number	Route	County	USCS Classif.[a]	AASHTO Classif.[b]
1	US-31	Hamilton	SM-SC	A-4(0)
2	SR-37	Hamilton	SC, SM-SC	A-4(0), A-2-4(0)
3	SR-37	Lawrence	CL, CH	A-6(15), A-7-6(34)
4	US-41	Sullivan	CL	A-6(8)
5	US-30	Laporte	SP-SM	A-3(0)
6	US-31	St.Joseph	SP	A-3(0)
7	SR-9	Noble	SW	A-1-a(0)
8	SR-43	Tippecanoe	CL	A-4(4)/A-6(5)
9	SR-63	Vermillion	GW	A-1-a(0)
10	US-36	Hendricks	CL	A-4(3)

[a] Unified Soil Classification System (ASTM, 1991)
[b] AASHTO Classification System (AASHTO, 1986)

specification limits for the fine sizes. This can be attributed to excess pore water pressure displacing the fines towards the pavement edge. This was further confirmed by clogged edge drains at these sites.

Soil-Moisture Properties Tests

Tests of soil-moisture properties were conducted to obtain hydraulic parameters for analysis of moisture migration in pavement layers. Parameters that were determined are a) matric suction/moisture content (ψ/θ) and b) hydraulic conductivity/moisture content (K/θ). Ten subgrade soils and five subbase materials were tested.

Suction-Moisture Test

Soil suction-moisture tests were carried out according to ASTM D-2325 and D-3152. These tests were conducted at the Purdue University Soil Physics laboratory of the Agronomy Department. The two test methods provide for determining capillary-moisture relationships for coarse and fine textured soils, respectively. Tests were determined on disturbed soil samples from augering and Shelby tube sampling.

Sample Preparation and Testing Equipment

Soil samples were prepared by air drying, pulverizing, and sieving through a No.10 (2.00mm) sieve. For stabilized subbase materials, two inch diameter undisturbed samples were

used. The soil suction-moisture content tests were conducted using a commercially available pressure membrane apparatus. The equipment operates in the 0-1 bar and 3-15 bar pressure ranges. In conducting the tests, soil samples were placed on a porous ceramic plate which is mounted in the extractor. The low pressure membrane apparatus can hold three ceramic plates, and the high pressure apparatus can hold one plate for each run, respectively. Figure 5.14 shows the setup of the two apparatuses with the pressure manifold system. The ceramic plates are approximately 10 inches in diameter, and have a metal screen and neoprene sheet backing to keep the bottom portion of the plate in contact with atmospheric pressure (Figure 5.15). On application of pressure in the chamber, a pressure difference is maintained across each porous plate. Water from the soil is forced out of the extractor through the ceramic plate and outflow tube due to the pressure differential. Flow ceases when an equilibrium moisture state is reached. Figure 5.16 shows a cross sectional view of the system.

Ceramic plates come with different pore size openings, permitting the tests to be run in 0-1 bar, 3, 5, and 10-15 bar pressure ranges. Prior to testing, the ceramic plates are soaked 3-4 days to ensure that all pores are filled with water which maintains a constant pressure difference through the plate.

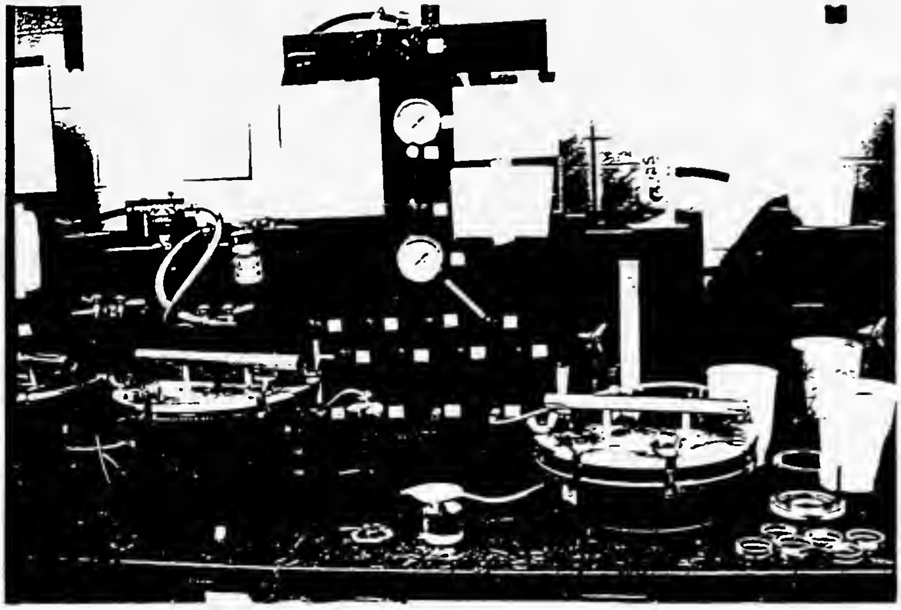


Figure 5.14 Setup of pressure chambers with manifold system

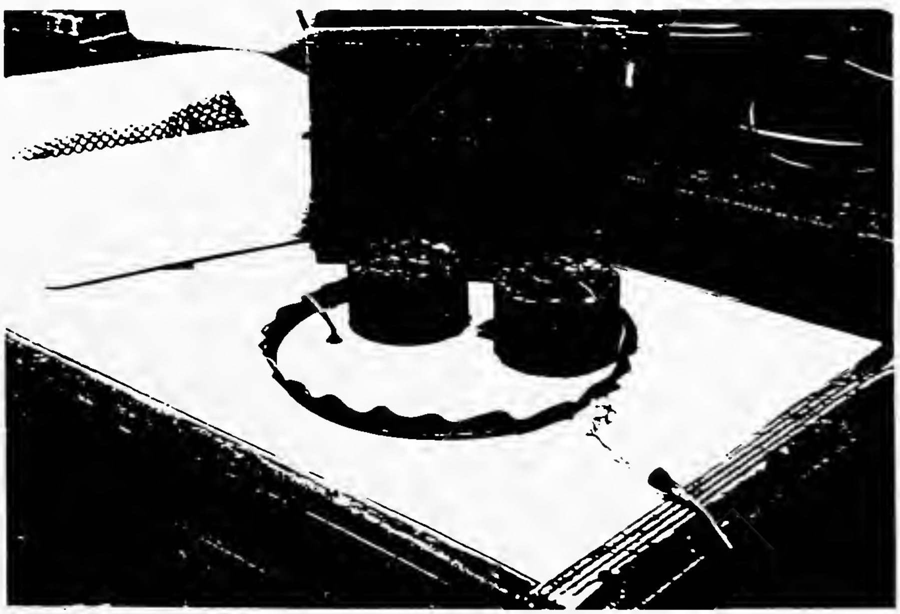


Figure 5.15 Subbase samples on soaked ceramic plate

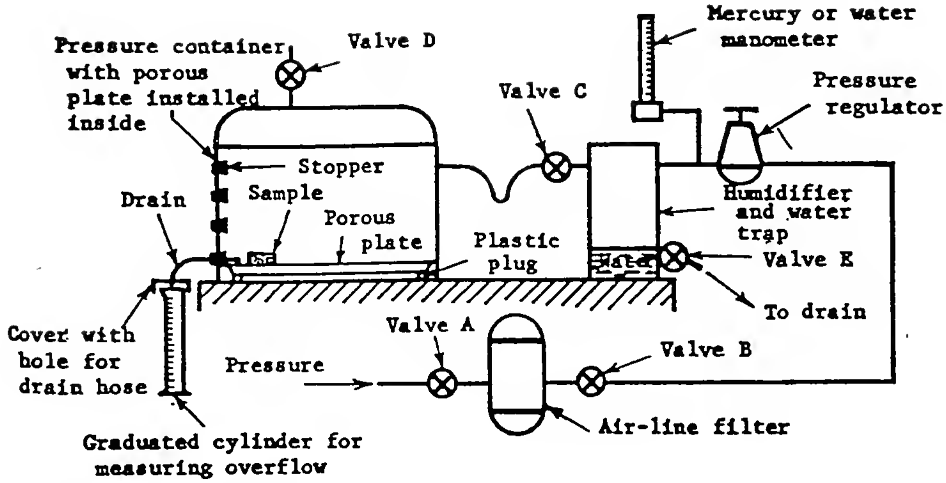


Figure 5.16 Sectional view of pressure chamber apparatus (ASTM, 1991)

Test Procedure

The general test procedure carried out for both pressure plate apparatuses was as follows: A soaked ceramic plate was mounted in the chamber. Soil samples weighing approximately 25 grams each were were poured into rigid plastic rings, 10mm (0.4 inch) in height with a 50mm (2 inch) inside diameter. Samples were levelled by pressing the top surface with a packer disk using an applied force of 9000 grams (Figure 5.17). Deaired water was added around the sample rings to saturate the samples for a 24 hour period.

At the end of the soaking period, excess water was removed with a pipette, and the extractor lid closed tightly to prevent air leakage. The end of the outflow tube was kept under water in a beaker to ensure a constant outflow environment and to check against air leaks from around the lid or through cracked ceramic plates. On initiation of the required pressure, water starts flowing into the beaker through the outlet tube. The equilibration time for each pressure was set to 3 days. Initial trials showed that no additional water draining after this period.

Pressures of 0.1, 0.33, 0.67, 1.0, 3.0, 5.0, and 15 bars were applied. Six replicates of each soil sample were tested for each pressure. At the end of each run, the outflow tube to the beaker was clamped to prevent water backflow and the pressure was slowly released. The specimens were transferred to containers and weighed. The specimens were then dried in an

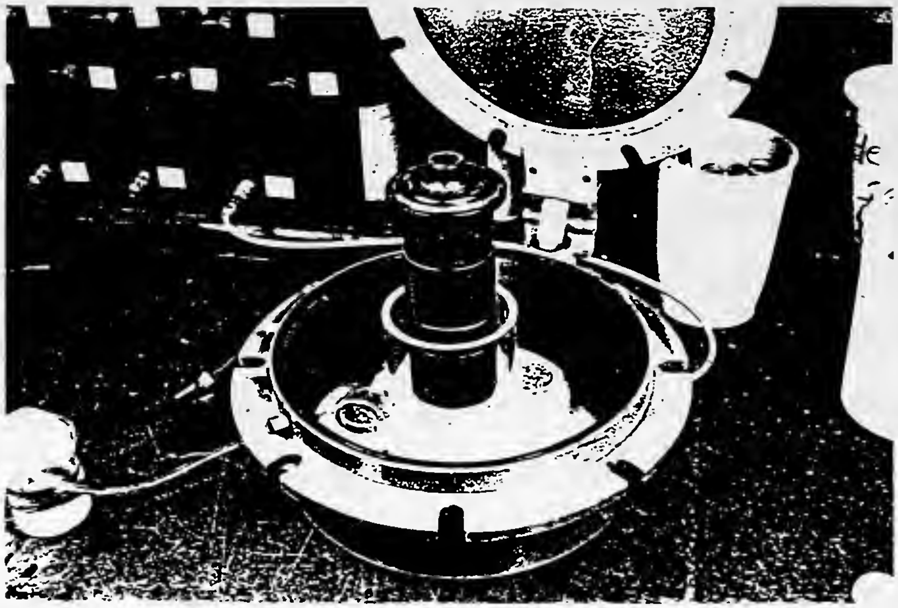


Figure 5.17 Packing soil samples with surcharge weight

oven at 110 °C for a 24 hour period and weighed. Moisture content values were calculated for each applied pressure and its relationship with matric potential was plotted. A data form for recording of the laboratory test results is presented in Figure 5.18. Figure 5.19 shows suction-moisture characteristic curves for the ten subgrade soils tested and Figure 5.20 shows similar curves for the subbase samples. Results of suction-moisture tests on subgrade soils and subbase materials are presented in Appendix D. Variability of the test results is also reported in the appendix.

Discussion of Results

ASTM does not give precision and accuracy statement for these tests. However, the variability between replicates was found to be within an acceptable range of moisture content for most sandy and clayey soils. Variability of results was more pronounced between auger samples and Shelby tube samples of granular soils. This can be attributed to the larger top size of these soils. Shelby tubes are 3 inches in diameter and may not provide a representative sample for coarse grained soils.

The shape of soil-water characteristics curves in Figure 5.19 indicate the sensitivity of soils to moisture changes. Cohesive soils retain more moisture than cohesionless soils even at high suction ranges. High plasticity clays retained the highest irreducible moisture content whereas poorly graded sands retained the lowest. Loams have irreducible moisture

CAPILLARY-MOISTURE RELATIONSHIP
FOR
BASE AND SUBGRADE SAMPLES
"PAVEMENT DRAINAGE PROJECT"

ROUTE NO: US-41 COUNTY SULLIVAN
CONTRACT NO: F-35 (11) SECTION SB
LOCATION SECTION SOUTH OF FARMERSBURG
SOIL TYPE: SILTY CLAY LOAM CLASSIFICATION CL; A-6(8)
IN-SITU MOISTURE CONTENT: 16.0 % SAMPLE TYPE DISTURBED
IN-SITU DENSITY: 134.05 PCF; POROSITY 51.9 %
SPECIFIC GRAVITY: 2.75 REMARKS:

(1) Tension, 1.0 BAR	AA	AS	BA	BS	CA	CS
(2) Container Number	4	5	6	7	8	9
(3) Wt. of container, +wet sample, g	29.51	29.57	29.47	29.31	29.57	29.42
(4) Wt. of container, +dry sample, g	25.41	25.37	25.26	25.04	25.34	25.18
(5) Wt. of moisture, g (3 − 4)	4.1	4.20	4.21	4.27	4.23	4.24
(6) Wt. of container g	1.31	1.31	1.31	1.06	1.29	0.98
(7) Wt. of dry sample, g (4 − 6)	24.10	24.06	23.95	23.98	24.05	24.20
(8) Moisture content, % ($\bar{\omega}$). (5 ÷ 7) x 100	17.01	17.46	17.58	17.81	17.59	17.52
(9) Unit wt. of dry sample, γ_d			1.66			
(10) Moisture content, vol. percent ($\bar{\omega}$) (8 x 9)			23.83			

$\bar{x} = 17.5\%$

Figure 5.18 Sample data form for soil-moisture tests

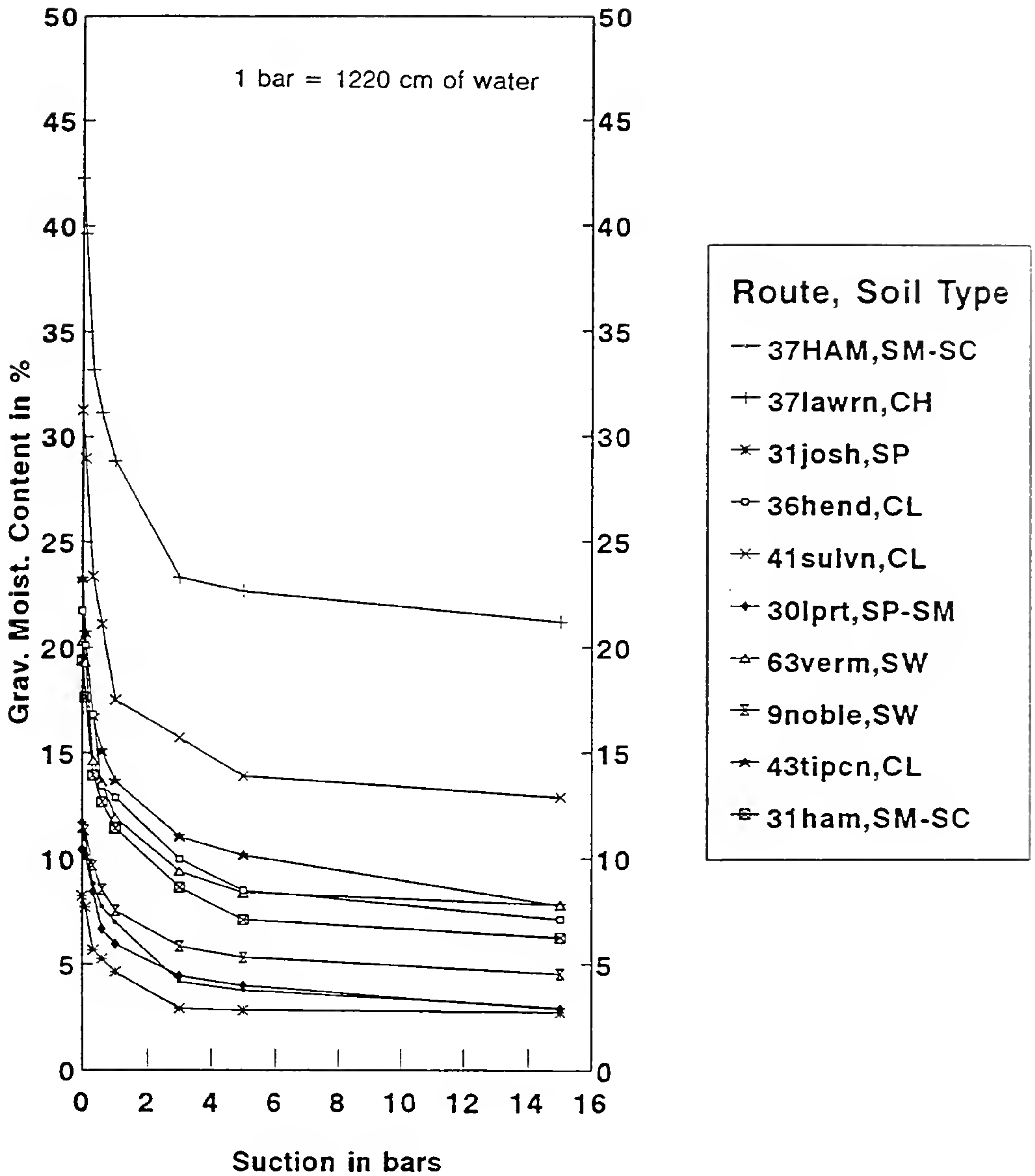


Figure 5.19 Soil-moisture characteristic curves of subgrade soils from instrumented sites

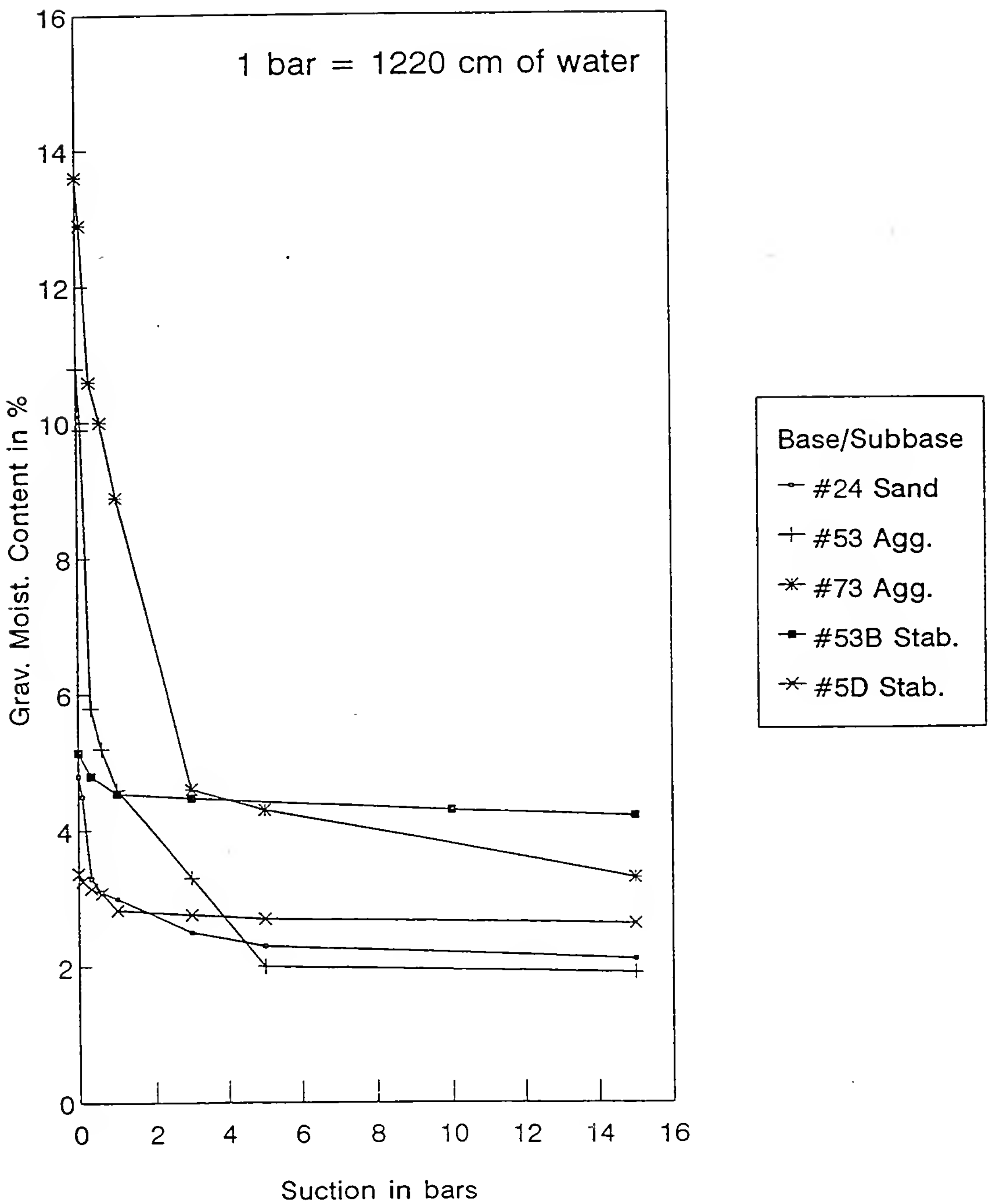


Figure 5.20 Soil-moisture characteristic curves of base and subbase soils

contents between the clays and sands. This can be attributed to the nature of the pore system. Sandy soils are composed of macroscopic particles and drain readily. Clayey soils, composed of microscopic particles, are highly impervious. However, some similarities are observed for all soils. The curves show a substantial drop in moisture content when the suction is increased to 1 bar. The curves then show a gradual decrease of moisture content until the suction reaches 5 bars. There is minimal water content decrease beyond the 5 bar range.

For subbase materials, the variation in moisture content for a large suction increase is low. The number 73 crushed aggregate and the 5D bituminous stabilized subbase had the highest and lowest variation in moisture content between suctions of zero and 15 bars, respectively. In general, the suction-moisture characteristics of unstabilized subbase materials are similar to sandy soils.

Parameter Development for Infiltration Models

Results of the laboratory measurements of soil-moisture characteristics of subgrades and subbase materials were used to obtain soil parameter values for the Brooks & Corey and Van Genuchten models incorporated in the PURDRAIN program. These models were described in Chapter 4.

Typical values for the fitting parameters PB and ν for the Brooks and Corey Model were determined by utilizing

suction and moisture content values for each subgrade and subbase type. The effective degree of saturation corresponding to each suction value was found using Equation 4.1. An iterative procedure was applied to determine the parameter values. The values were then fitted into the model and checked against experimental results. A similar procedure was adopted for the determination of α, β and γ values for the Van Genuchten model using Equation 4.4.

Table 5.2 lists the parameter values for both models and Figures 5.21 and 5.22 provide a comparison of the measured vs estimated $\psi(\theta)$ function for one subgrade soil using Brooks & Corey and Van Genuchten models, respectively. Comparisons for other soils are shown in Appendix E. The plots show the estimated values are in close agreement with measured values for both models at low suction values. Similar results were obtained for the remaining subgrade soils and subbase materials. As most of the moisture movement takes place at low suction or at higher moisture contents, the results seem to be valid. A regression analysis was conducted for calibration purposes between measured values of effective degree of saturation and values predicted by Brooks & Corey's and by Van Genuchten's models for subbase materials and subgrade soils. High correlations were obtained for both models as shown in Table 5.3. Regression results are included in Appendix E.

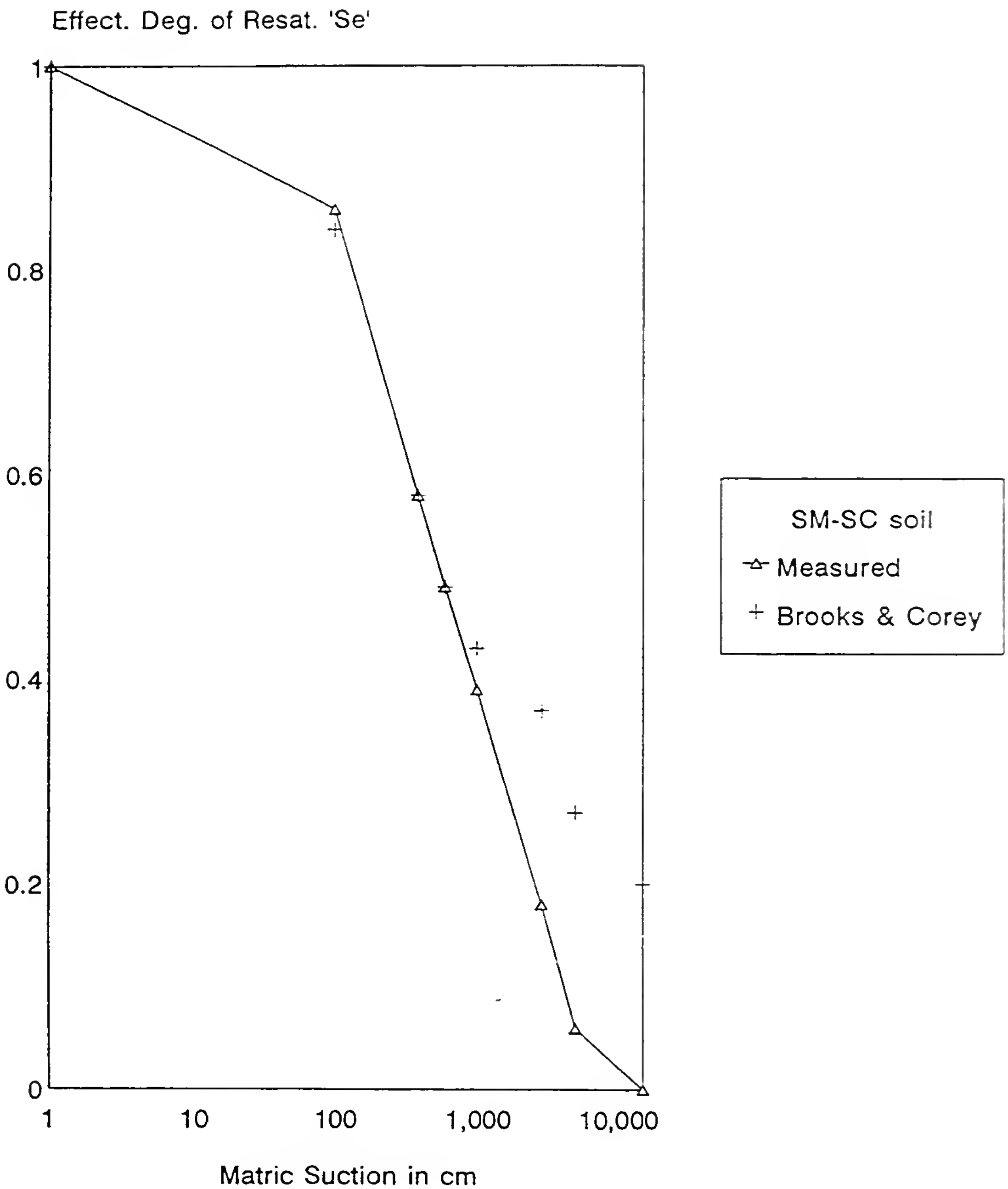


Figure 5.21 Measured vs Estimated Brooks & Corey function

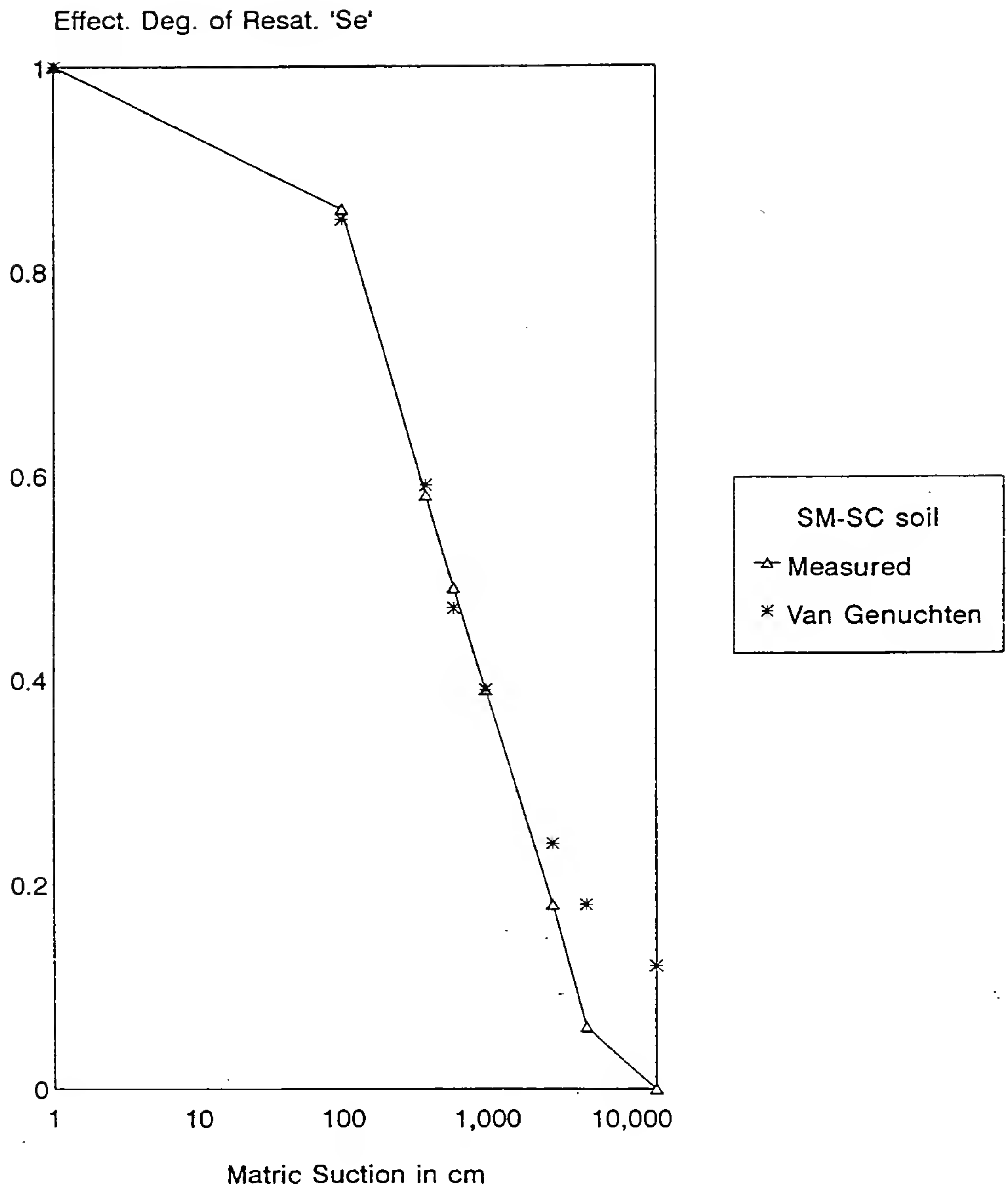


Figure 5.22 Measured vs Estimated Van Genuchten function

Table 5.2 Hydraulic Parameter Values of Subgrade Soils

Route/ County or Base #	Soil Type[a] or Base Type[b]	Brooks & Corey Model		Van Genuchten Model		
		PB cm	ν_d	α cm^{-1}	β	γ
US-31 Hamilt	SM-SC	52	3.1	.008	1.45	0.31
SR-37 Hamilt	SC	68.5	3.18	.0054	1.46	0.315
SR-37 Lawrnc	CH	67.5	2.8	.0048	1.665	0.399
US-41 Sullvn	CL	60	3.0	.008	1.48	0.324
US-30 Laprt	SP-SM	87	2.6	.0029	1.80	0.444
US-31 StJosh	SP	78	2.34	.0048	1.665	0.339
SR-9 Noble	SW	82	3.2	.00245	1.87	0.465
SR-43 Tippcn	CL	61.5	3.0	.013	1.35	0.259
SR-63 Vermil	GW	80	2.31	.0048	1.68	0.405
US-36 Hendrk	CL	72	2.78	.00625	1.502	0.334
Base1	#24	73	2.5	.0064	1.569	0.363
Base2	#53	79	1.92	.0052	1.735	0.423
Base3	#73	85	3.15	.0028	1.55	0.355
Base4	#53B	122	2.3	.0028	1.685	0.4065
Base5	#5D	88	2.11	.0028	1.685	0.4065

[a] Unified Soil Classification System (ASTM,1991)
[b] Standard Specifications (IDOH,1988)

Table 5.3 Goodness of fit values for estimated parameters

Route/Cnty or Base No.	Soil Type[a] or Base Type[b]	Goodness of Fit 'R^2' values	
		Brooks & Corey Model	Van Genuchten Model
US-31 Hamilton	SM-SC	0.929	0.912
SR-37 Hamilton	SM-SC	0.724	0.879
SR-37 Lawrence	CH	0.815	0.976
US-41 Sullivan	CL	0.729	0.895
US-30 Laporte	SP-SM	0.908	0.991
US-31 St.Joseph	SP	0.846	0.851
SR-9 Noble	SW	0.750	0.996
SR-43 Tippecanoe	CL	0.890	0.866
SR-63 Vermillion	GW	0.927	0.978
US-36 Hendricks	CL	0.870	0.948
Base No.1	#24	0.965	0.961
Base No.2	#53	0.919	0.944
Base No.3	#73	0.670	0.867
Base No.4	#53B	0.940	0.965
Base No.5	#5D	0.829	0.934

[a] Unified Soil Classification System (ASTM,1991)
[b] Standard Specifications (IDOH,1988)

Permeability

As described in Chapter 2, Darcy's Law is used to estimate the hydraulic conduct ivity or permeability of saturated materials. Permeability is the only property which varies widely for a given material, and cannot be considered to be a constant for a given type of subbase or subgrade. A range of expected values for permeability of different soils have been given by Lambe (1951), Terzhagi and Peck (1967), and Freeze and Cherry (1979). Figure 5.23 shows typical ranges for soils and rocks.

Permeability measurements were made on soil samples obtained from test sites using constant head and falling head permeameters which are described below. A constant head permeability test was used for coarse grained soils, whereas falling head method was employed for fine grained soils. Undisturbed soil samples could not be obtained for granular soils and therefore the constant head permeability test was run on disturbed soil samples. Tests of cohesive soils were made using Shelby tube samples.

INDOT Division of Materials and Tests had performed tests to determine permeability of typical base and subbase materials used in the state. To avoid duplication of effort, permeability tests on base and subbase materials were not performed and results obtained by INDOT were used, see Table 5.4. A field permeability testing device (FPTD) on loan from the FHWA was used to carry out permeability tests on #53

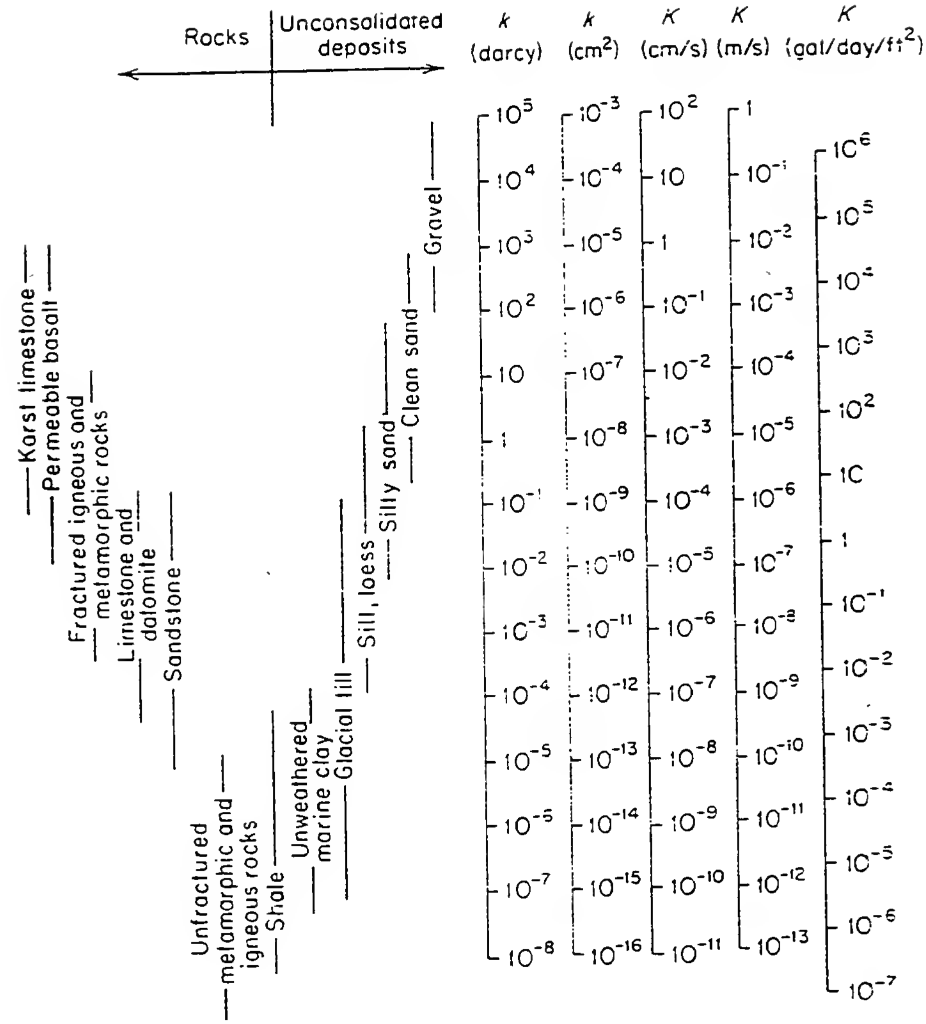


Figure 5.23 Range of permeability for soils and rocks (Freeze and Cherry, 1979)

Table 5.4 Permeability Values of INDOT Base Materials[a]

Material	Pemeability 12" head cm/sec	Permeability 24" head cm/sec	Average Permeability ft/day
#24 Sand w/ 3% passing #200 sieve	0.96×10^{-3}	1.1×10^{-3}	1.4
#24 Sand w/ 6% passing #200 sieve	4.1×10^{-4}	4.5×10^{-4}	1.2
#53 Stone w/ 5% passing #200 sieve	-	-	0.10
#53 Stone w/ 10% passing #200 sieve	-	-	0.12
#53 Special Subbase 100% Crushed	-	-	499
#73 Stone w/ 7½% passing #200 sieve	7.03×10^{-2}	6.53×10^{-2}	192
#73 Stone w/ 10% passing #200 sieve	4.22×10^{-2}	3.29×10^{-2}	106
#53B base w/ 2½% passing #200 sieve	2.98×10^{-2}	2.23×10^{-2}	74
#53B base w/ 5% passing #200 sieve	0.95×10^{-2}	0.84×10^{-2}	25
#5D HAC base	2.02×10^{-4}	1.93×10^{-4}	0.6

[a] Source: INDOT Division of Materials and Testing

subbase. Permeability values obtained were compared with results achieved by INDOT on similar sample. The FPTD is described later.

Constant Head Permeameter

A constant head permeameter was fabricated at Purdue University for testing granular soils with larger aggregates. The permeameter is rigid-wall type and has an 8 inch (20 cm) internal diameter. Specimens can be placed to a height of 12 inches inside the cylinder. The height of the inflow chamber is fixed, whereas the outflow chamber height can be adjusted prior to testing. This ensures that a desirable height difference can be achieved between the two chambers. A series of manometers are connected to the permeameter at various points. A setup of the permeameter is shown in Figure 5.24.

Soil samples obtained from test sites were air dried and pulverized with a wooden mallet. Care was taken to avoid crushing particles. The samples were wetted uniformly in stages to the desired moisture content using a spray bottle, and placed in a temperature controlled chamber prior to testing. The prepared soils were then placed in the permeameter and compacted with a standard compactive effort of 12,375 ft-lb (Holtz and Kovacs, 1981) using a sliding weight tamper. Permeability tests were run according to ASTM D-2434. Coefficient of permeability of the samples were calculated using the relation:

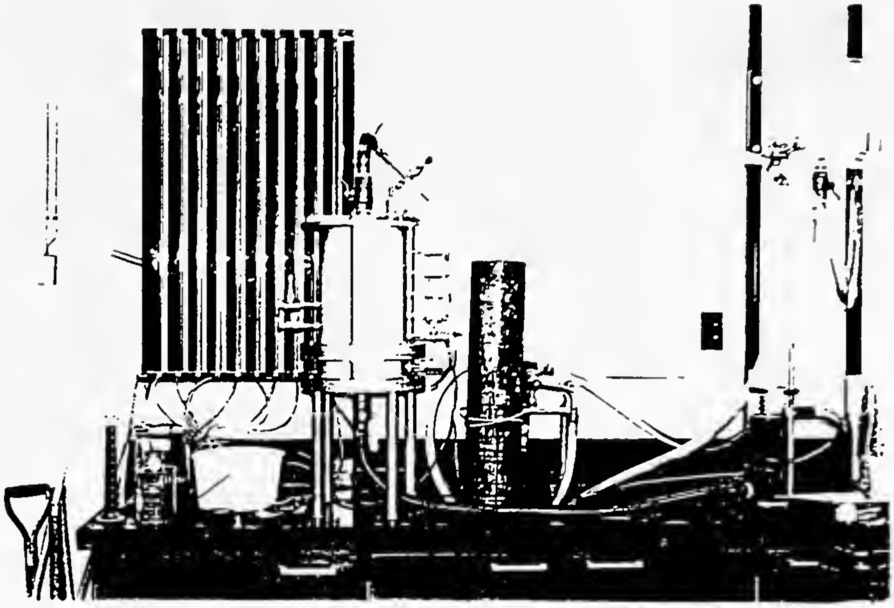


Figure 5.24 Setup of the constant head permeameter

$$k=\frac{QL}{Ath} \tag{5.2}$$

where: k = coefficient of permeability
Q = quantity of flow
L = height of compacted specimen
A = cross-sectional area of specimen
h = head difference between upper and lower chambers
t = time of discharge measurement

Falling Head Permeameter

Falling head permeability tests were conducted on four subgrade soil types using a flexi-wall permeability cell. The cell and its permeameter control column are shown in Figure 5.25. Soil samples were extruded from Shelby tubes using a hydraulic sample extruder. For each sample, a latex membrane was fitted inside a plastic cylinder equal in diameter to the shelby tube. A vacuum of 2 psi was employed to remove air trapped between the membrane and the cylinder. The sample was placed inside the cylinder and the top and bottom surfaces levelled. On releasing the vacuum, the membrane adjusted to the contours of the soil sample. This was necessary to avoid piping around the edges during permeability testing.

Samples were subsequently placed inside the permeability cell and tubing connections made to the regulator valves. Sample saturation was initiated by first applying a vacuum of 11 psi to remove entrapped air from the sample. This was followed by applying an initial backpressure of 5 psi and recording the water intake. When water intake stopped, backpressure was raised another 5 psi and the process

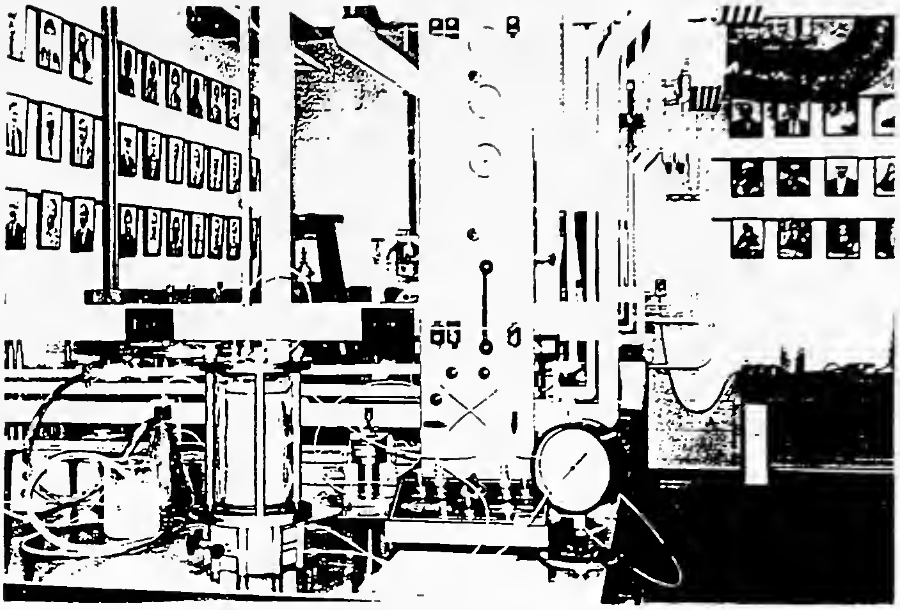


Figure 5.25 Flexi-wall permeameter cell and control column

repeated. The elapsed time between increments depend entirely on the permeability of the sample. The backsaturation process was terminated when less than 0.1 cc of water intake was recorded for a 5 psi increment in backpressure. According to information supplied with the permeameter, this criteria results in a state close to 100% saturation.

Permeability measurements were made by recording the drop in water level for a suitable time interval. Three tests were conducted on each sample and the average water drop determined. These data are used in equation 5.3 (Holtz and Kovacs, 1981) to evaluate permeability.

$$k = 2.3\frac{aL}{At}\log\frac{h_1}{h_2} \qquad 5.3$$

where:
- k = coefficient of permeability
- a = cross sectional area of standpipe
- L = length of soil specimen
- A = cross sectional area of specimen
- t = time of water drop measurement
- h_1 = initial height of water column
- h_2 = final height of water column

Field Permeability Testing Device (FPTD)

The Field Permeability Testing Device (FPTD) was developed by Moulton and Seals (1979) for the Federal Highway Administration (FHWA). Use of the device involves:

i) establishing a saturated, steady state flow in the base or subbase layer by injecting water through a port located at the center of a circular plate. Water is added until the layer becomes fully saturated. Figure 5.26

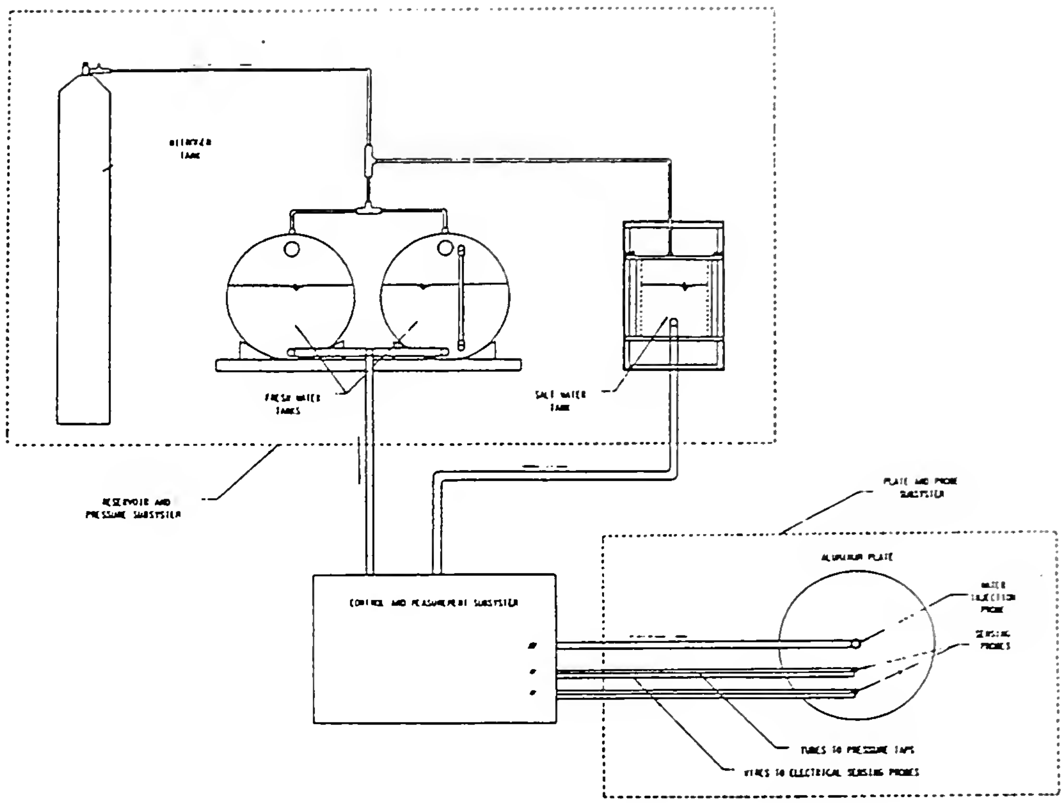


Figure 5.26 Schematic of Field Permeability Testing Device (Moulton and Seals, 1979)

shows a schematic of the permeability device.

ii) determining flow velocity from the time of seepage along a streamline or flow path between two points that are a known distance apart. This is achieved by injecting an electrolytic solution (Ammonium Chloride mixed with water) through the injection port. The time for the electrolytic solution to flow between two points on a streamline is sensed by means of electrical probes.

iii) determining the head loss between the sensing probes by measuring fluid pressures with differential pressure transducers at the ends of the electrical conductivity probes.

The coefficient of permeability is calculated by the relation (Moulton and Seals, 1979):

$$k = \frac{L^2 n}{t(\Delta h)} \qquad 5.4$$

where:
k = coefficient of permeability
L = probe spacing
n = porosity of the material
t = time of flow between probes
Δh = head loss between two points

The FPTD was acquired from FHWA for a limited time to determine in-situ permeabilities of base materials used in Indiana. Unfortunately, during this period, no base course was exposed on any ongoing highway project. It was therefore not possible to use the device on field projects. A decision was made to test base samples in the laboratory using the FPTD device.

Operation of FPTD

As shown in Figure 5.27, a 4 ft x 4 ft x 1 ft height test chamber was fabricated with drain outlets at one end. Indiana #53 crushed aggregate material was placed in the chamber and compacted with a tamping rod to a depth of six inches. The horizontal plate of the FPTD was positioned on the aggregate surface with the water injection and sensing probes inserted through the plate into predriven holes. A surcharge weight was placed on the plate and transducer and electrical connections made. Water flow was initiated through the system. A steady state flow was indicated by water flowing out of the drain tubes at the bottom of the chamber.

A charge of electrolytic solution was introduced into the subbase through the water injection port. When the electrolytic solution passes the upstream probe the timing mechanism is triggered. Time of flow is determined when the solution passes the downstream probe, and head differential is displayed on the measurement subsystem (Figure 5.28). The test is completed by flushing the system with fresh water.

Functional Problems of FPTD

Several problems were encountered during operation of the FPTD. The nature of the material tested made driving and removing the rods used to form the holes for the injection and sensing probes difficult. Piping was observed around the plate with the water supply valve full open. The function of the sensing probes was also erratic. In some cases, neither probe

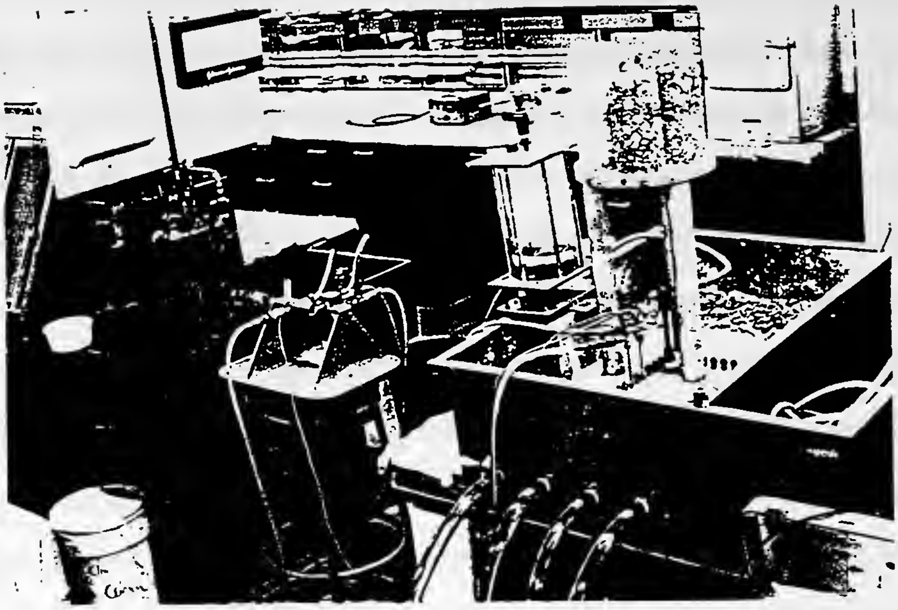


Figure 5.27 Setup of Field Permeability Testing Device

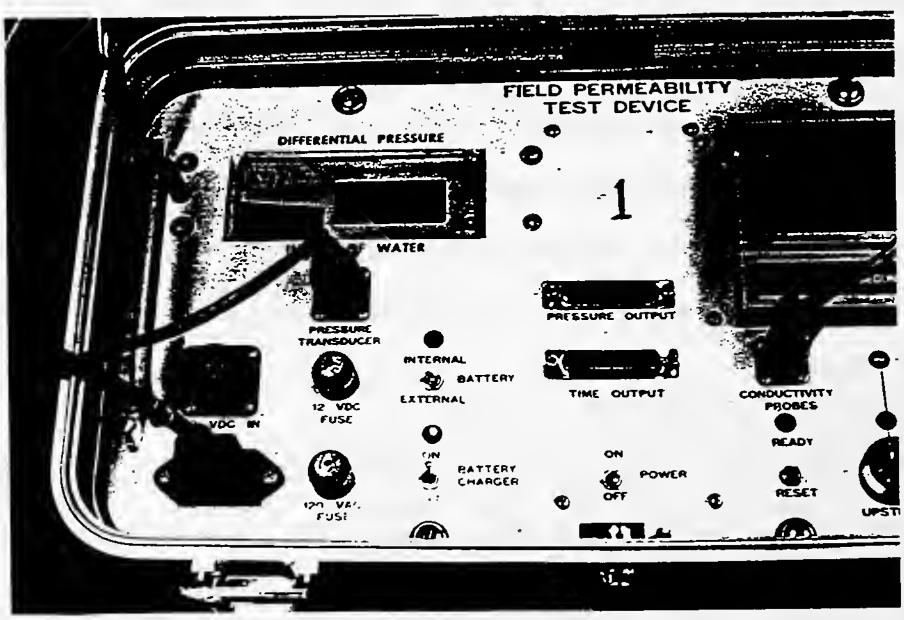


Figure 5.28 Measurement subsystem of FPTD

triggered the timing mechanism and in others, only one probe functioned. This could be attributed to the electrolytic solution bypassing the upstream or downstream probe.

To overcome problems with the probe, they were placed one inch apart and away from the central injection port. Water flow was initiated slowly to avoid piping. This resulted in better response.

After five runs were made, the differential pressure transducer stopped working. Problems were noted and the unit was returned to FHWA.

Discussion of Results

Results from the constant and falling head permeability devices on subbase materials and subgrade soils and from the Field Permeability Testing Device on the #53 subbase are listed in Table 5.5. The measured coefficients of permeability were compared with the values given by Freeze and Cherry (1976) for soils and with INDOT values for the #53 subbase. It is observed that laboratory determinations of permeability for the subgrade soils lie within the range specified for each soil type. Permeability value for the #53 subbase is also close to the INDOT specified value. Permeability of other bases could not be tested with the FPTD because of functional problems.

Table 5.5 Permeability values of subgrade and subbase soils

Route/County or Base Type	Soil Type[a]	Permeameter Type	Coefficient of permeability cm/sec
US-31 Hamilton	SM-SC	Flexi-wall	2.44×10^{-6}
SR-37 Hamilton	SM-SC	Flexi-wall	1.31×10^{-4}
SR-37 Lawrence	CH	Flexi-wall	2.10×10^{-7}
US-41 Sullivan	CL	Flexi-wall	6.03×10^{-4}
US-30 Laporte	SP-SM	Constant Head	1.05×10^{-3}
US-31 St.Joseph	SP	Constant Head	2.09×10^{-3}
SR-9 Noble	SW	Constant Head	3.37×10^{-3}
SR-43 Tippecanoe	CL	Flexi-wall	5.09×10^{-5}
SR-63 Vermillion	GW	Constant Head	5.97×10^{-3}
US-36 Hendricks	CL	Flexi-wall	1.10×10^{-5}
Subbase	#53[b]	FPTD	0.168

[a] Unified Soil Classification System (ASTM, 1991)
[b] Standard Specifications (IDOH, 1988)

Chapter Summary

A comprehensive laboratory investigation was completed to identify the subbase materials and subgrade soils obtained from instrumented test sites. Permeability measurements were made using specially designed constant head and state-of-the-art flexi-wall permeameters. The FHWA Field Permeability Testing Device was evaluated. Determination of the hydraulic properties of a wide variety of subbase materials and subgrade soils has resulted in development of a database, which can be used with the PURDRAIN program in analyzing moisture infiltration in pavement structures. Parameters were estimated for foundation soils and subbases for the two constitutive models built into the PURDRAIN program.

CHAPTER 6 - DATA ANALYSIS AND DISCUSSION

The drainage study incorporated ten pavement sections. Two of these sections did not have edge drains. Outflow volumes could not be recorded for SR-37, Hamilton County test site due to malfunctioning of the tipping bucket flow meter as described in Chapter 4. Data from test sections were reduced to a spreadsheet format. The data was further analyzed to isolate individual precipitation events and corresponding outflow volumes for each test site.

Each test section length was selected to correlate with the distance between the instrumented and upstream outlets, as obtained through profile readings. For sections on sag curves, the length considered was between outlets, preceding and following the instrumented outlet. Water obviously would flow from both directions towards the instrumented outlet. The width of the section was taken as the distance to the trench for pipe edge drains, and to the pavement-shoulder joints for prefabricated edge drains. Table 6.1 shows precipitation and outflow data from seven test sections, for which outflow volumes were recorded. Condition of the pavement-shoulder joints are also displayed for analysis purposes. For consistency, the sections are numbered in the same order as in

Table 6.1 Information on precipitation and outflow volumes

ROUTE	SECT No.	PVMT. TYPE	DRAIN TYPE	CUMUL PRECP cft	CUMUL FLOW cft	PCI/ DISTRESS	OFLOW/ PRECP. VOLUME %
US-31, HAMILT	1	CONC.	PIPE	665 2815 2042	36.8 1137 542.0	71.1 EDGE CRACK/JT SEAL DAMAGE	5.53 40.40 26.52
US-36, HENDRK	10	CONC.	PIPE	251 502 377	175.5 161.5 127.5	96.6 EDGE CRK	69.82 32.12 33.83
US-41, SULLVN	4	CONC.	FIN	347 179	208.1 61.9	79.2 EDGE CRK /SHLDR. DAMAGE	59.92 34.63
SR-63, VERMLN	9	ASP.	PIPE	69 120	34.9 50.0	36.8 MAJOR DISTRESS	50.64 41.72
SR-9, NOBLE	7	ASP.	PIPE	1479	389.2	94.6 EDGE CRK	26.31
US-30, LAPORT	5	OVRLY	FIN	150 1520 2290 75 1030	2.0 36.5 8.1 1.7 29.1	86.3 EDGE CRK /REFLEX. CRK	1.35 2.40 2.84 2.21 2.82
US-31, STJOSH	6	OVRLY	FIN	1845 768 974	4.4 4.0 1.0	77.0 EDGE CRK /REFLEX. CRK	0.24 0.51 0.10

Table 4.1. Figures 6.1 to 6.19 show precipitation and outflow as functions of time for the test sections. Data sets for the test sites are listed in Appendix F.

Precipitation vs Outflow

A study of Figures 6.1 to 6.19 show the outflow response to be instantaneous with precipitation for all test sites, except for data set 1 at US-31, Hamilton County. For this recorded precipitation event, pipe outflow lags by several hours. This might be attributed to the low precipitation intensity as well as the base being in a relatively dry condition prior to the rainfall event. These figures also indicate that 40 to 60 percent of the cumulative outflow volume takes place within the first four hours. The outflow volumes then continue to diminish over a period of 24 hours except when there is a second rainfall event within this period. This triggers an immediate rise in outflow volumes.

The immediate response to precipitation is attributed to the pavement-shoulder joint condition at these sites. Condition surveys indicated edge cracking, longitudinal and transvers cracks or poorly sealed pavements at all the test sites. This resulted in higher percent of water infiltrating through the cracks and joints at the start of a precipitation event. Once the pavement cracks and pores of the subbase become saturated, the infiltration into the pavement layers will depend upon the rate at which water flows laterally in

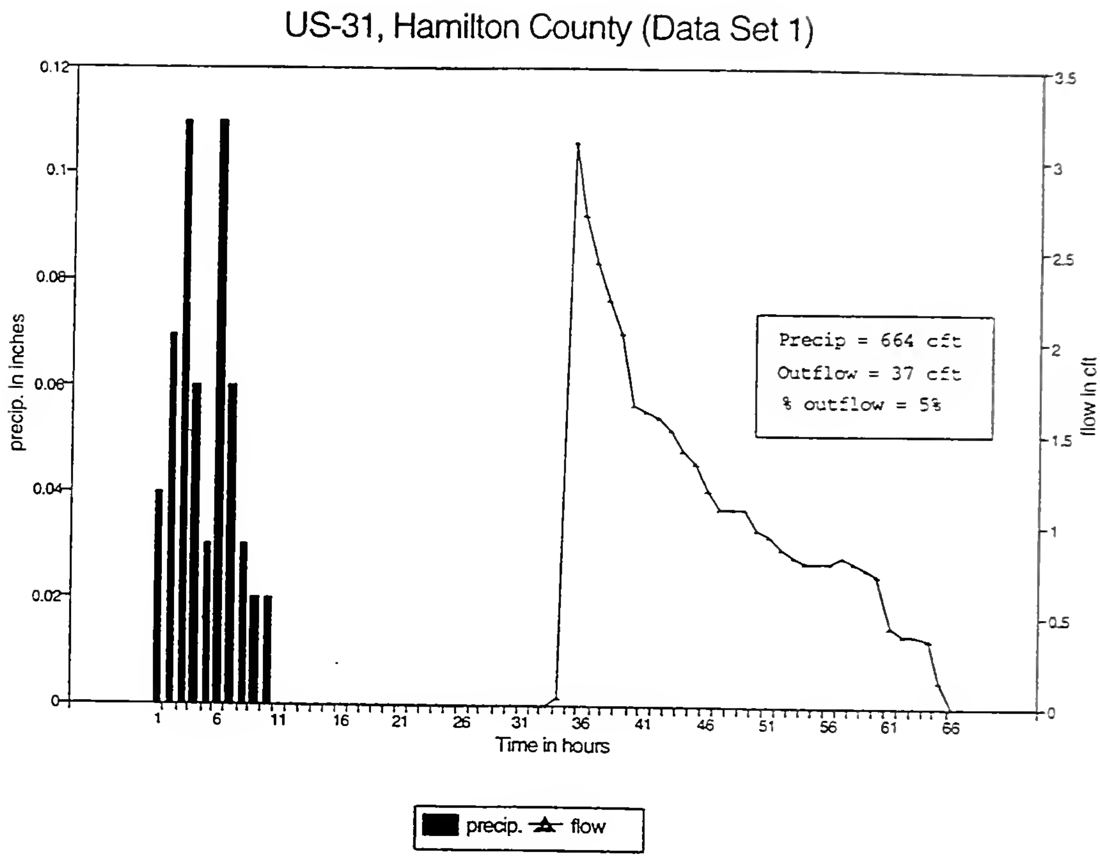


Figure 6.1 Influence of precipitation on outflow volume (US-31, Hamilton County; Data Set 1)

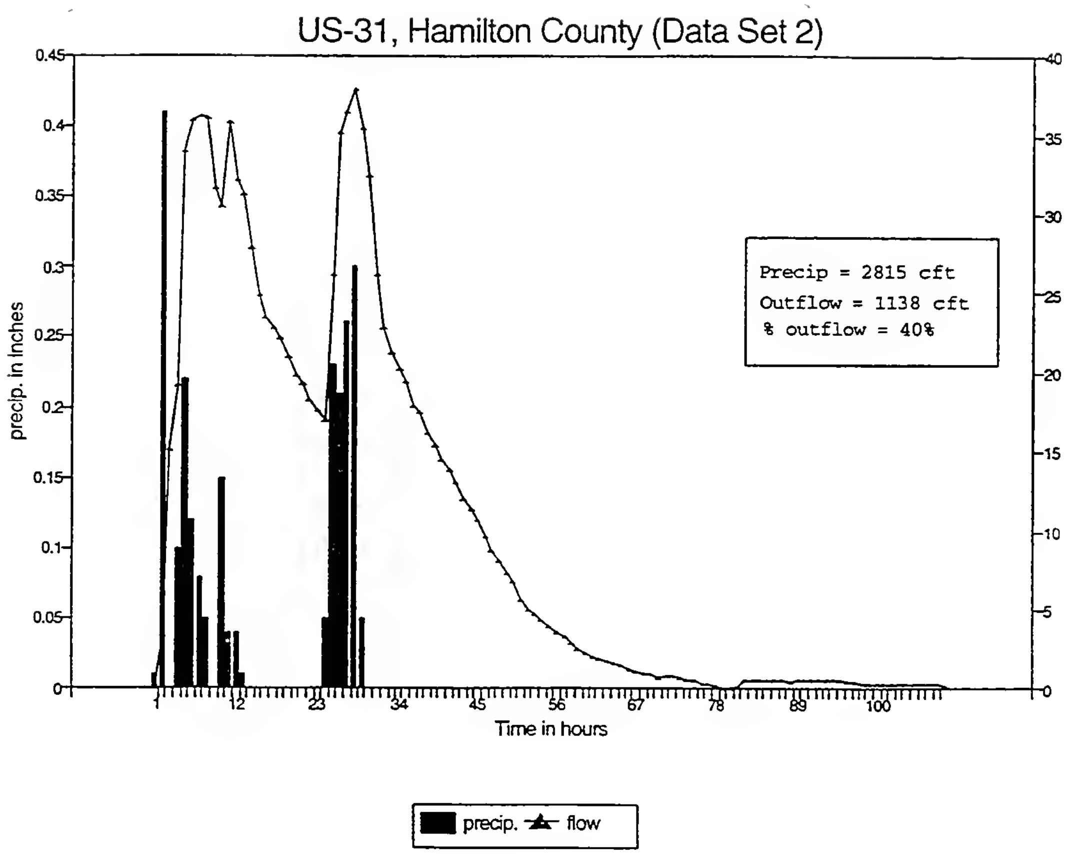


Figure 6.2 Influence of precipitation on outflow volume (US-31, Hamilton County; Data Set 2)

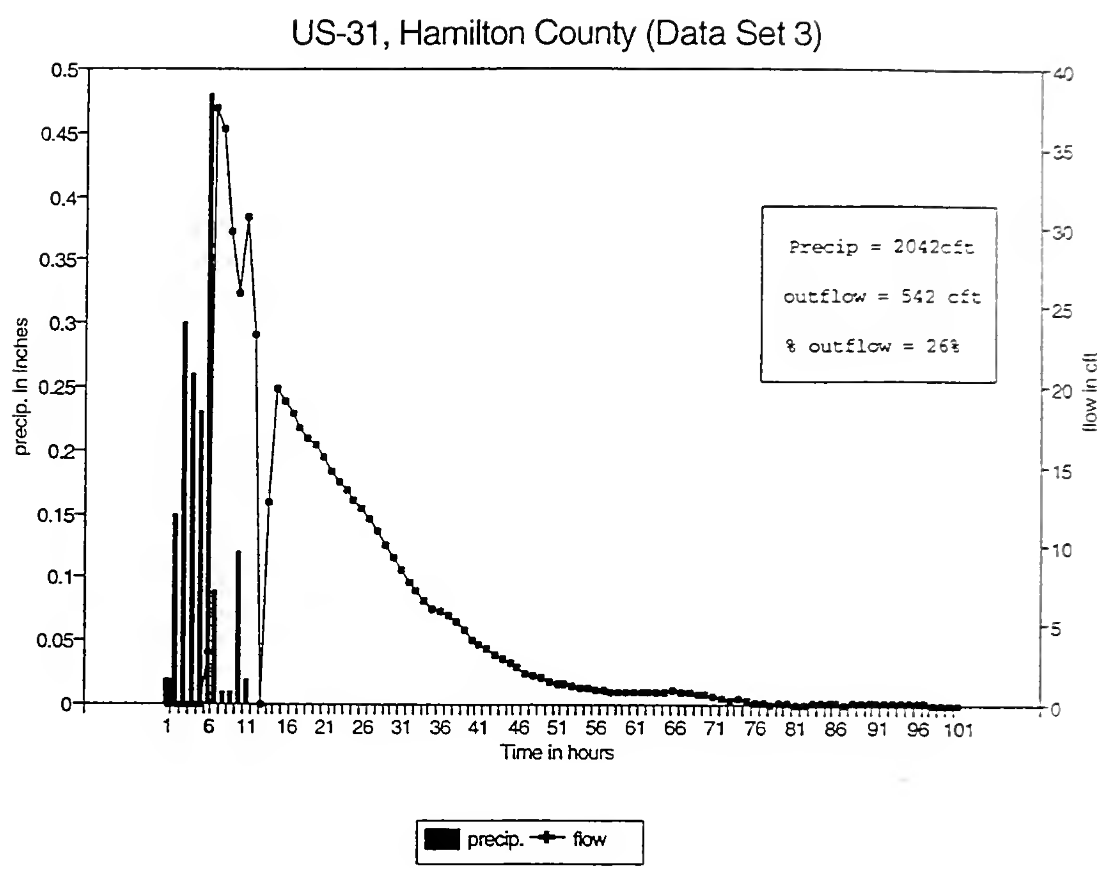


Figure 6.3 Influence of precipitation on outflow volume (US-31, Hamilton County; Data Set 3)

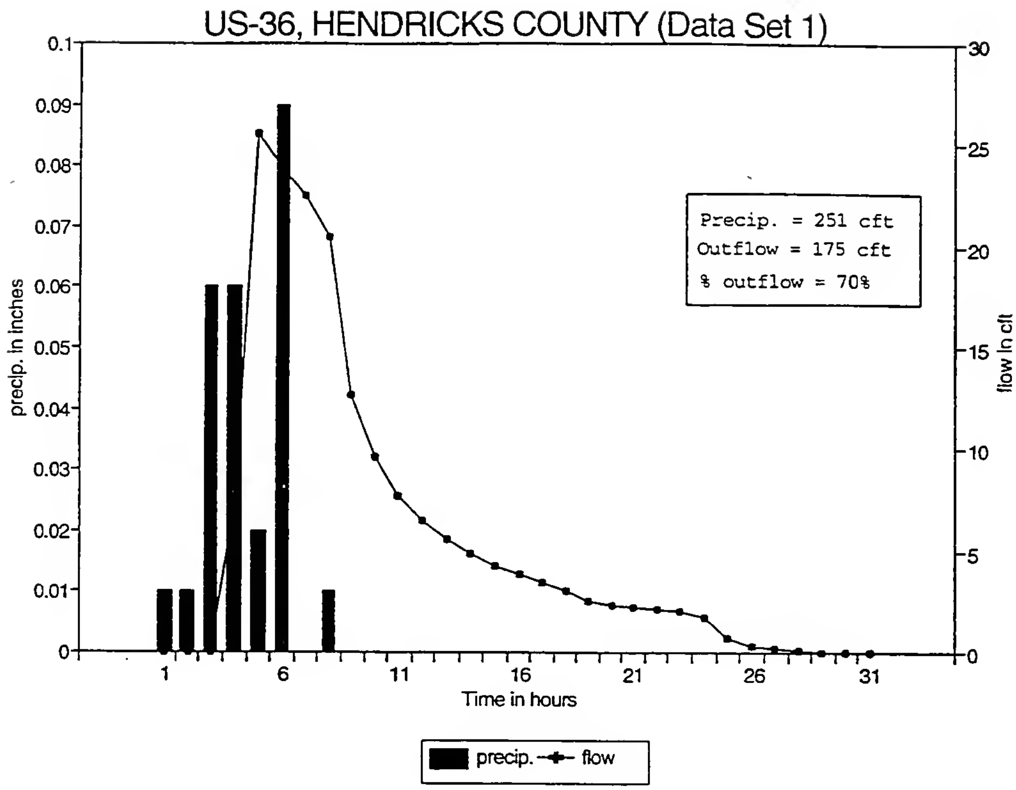


Figure 6.4 Influence of precipitation on outflow volume (US-36, Hendricks County; Data Set 1)

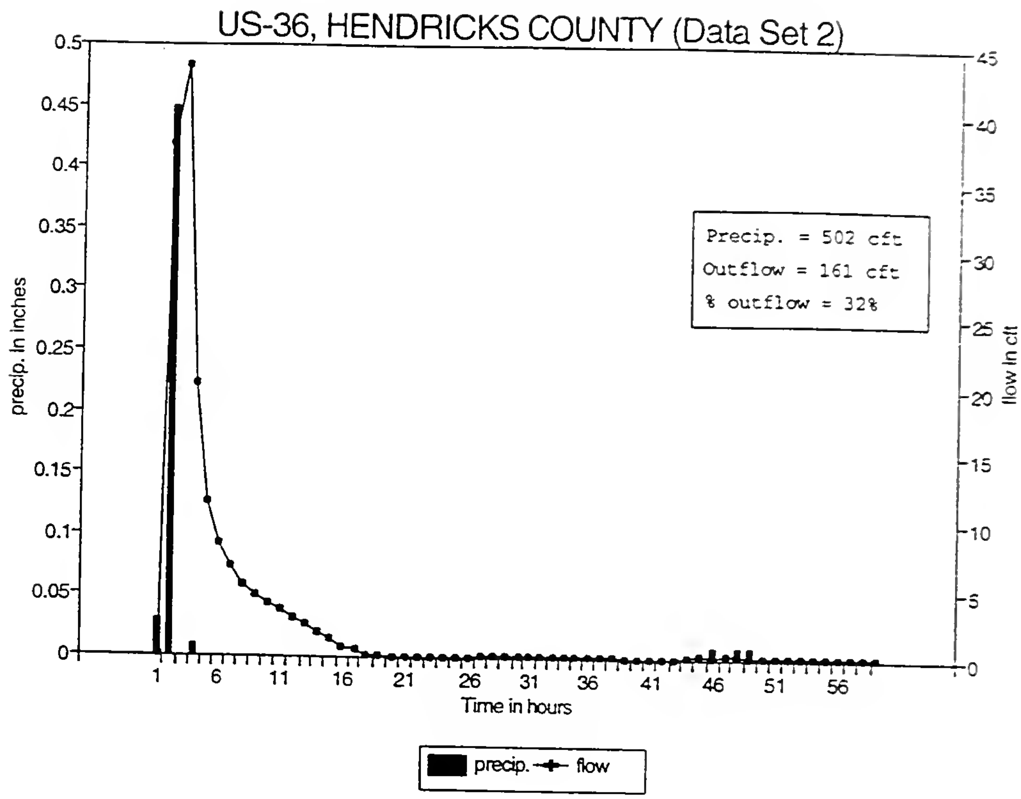


Figure 6.5 Influence of precipitation on outflow volume (US-36, Hendricks County; Data Set2)

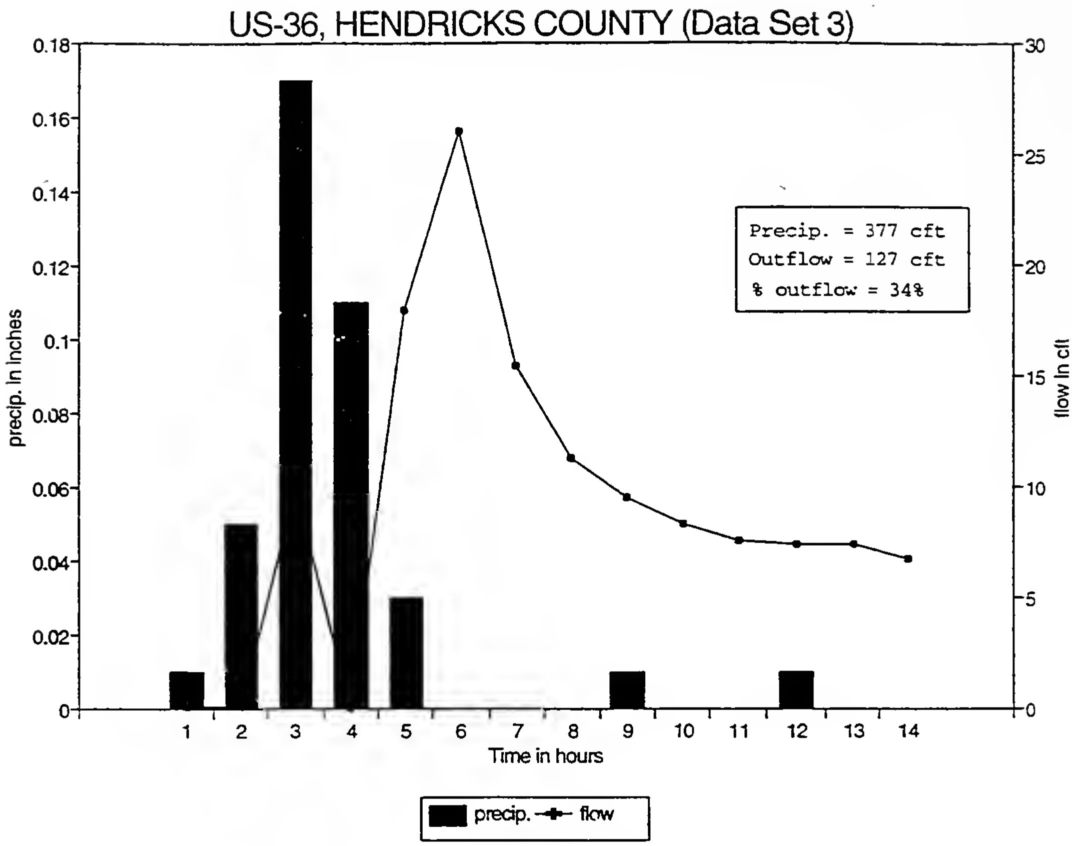


Figure 6.6 Influence of precipitation on outflow volume (US-36, Hendricks County; Data Set 3)

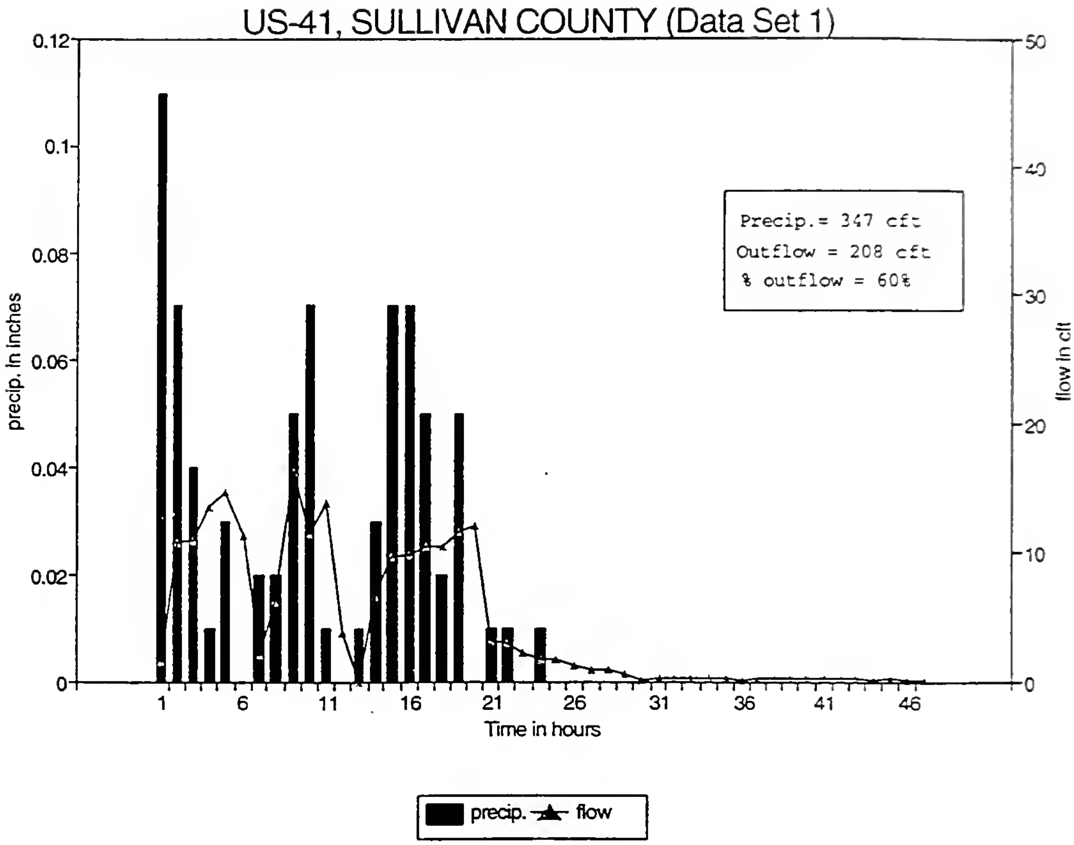


Figure 6.7 Influence of precipitation on outflow volume (US-41, Sullivan County; Data Set 1)

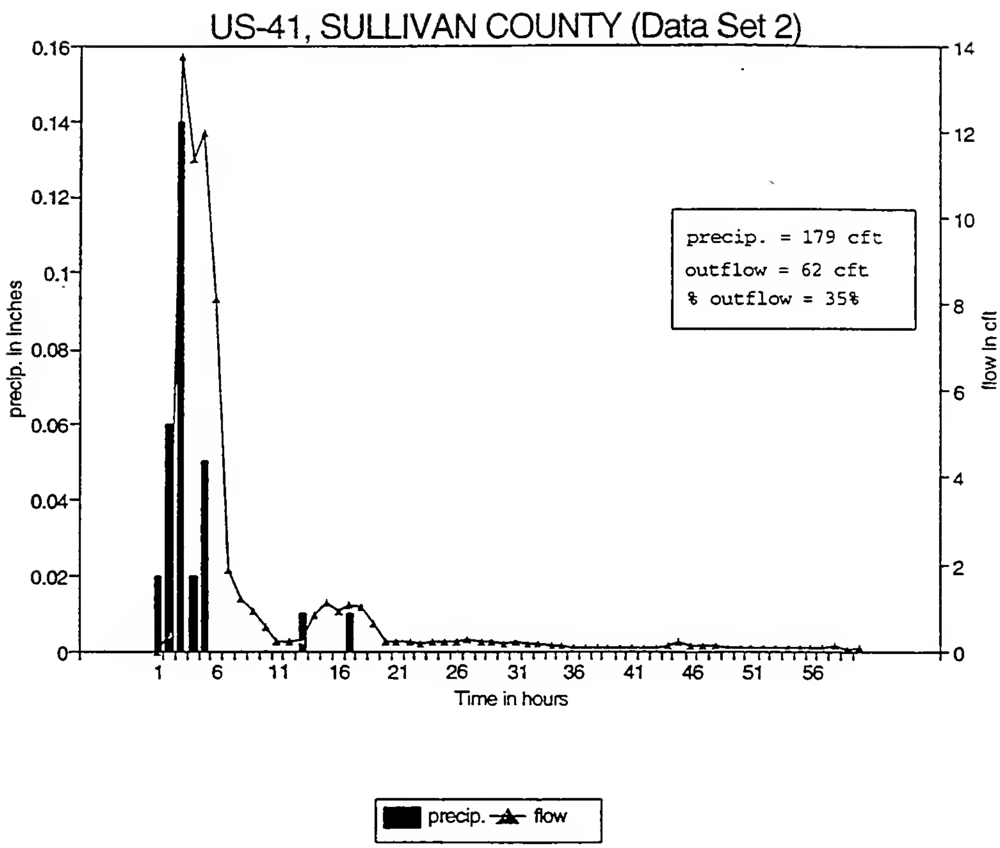


Figure 6.8 Influence of precipitation on outflow volume (US-41, Sullivan County; Data Set 2)

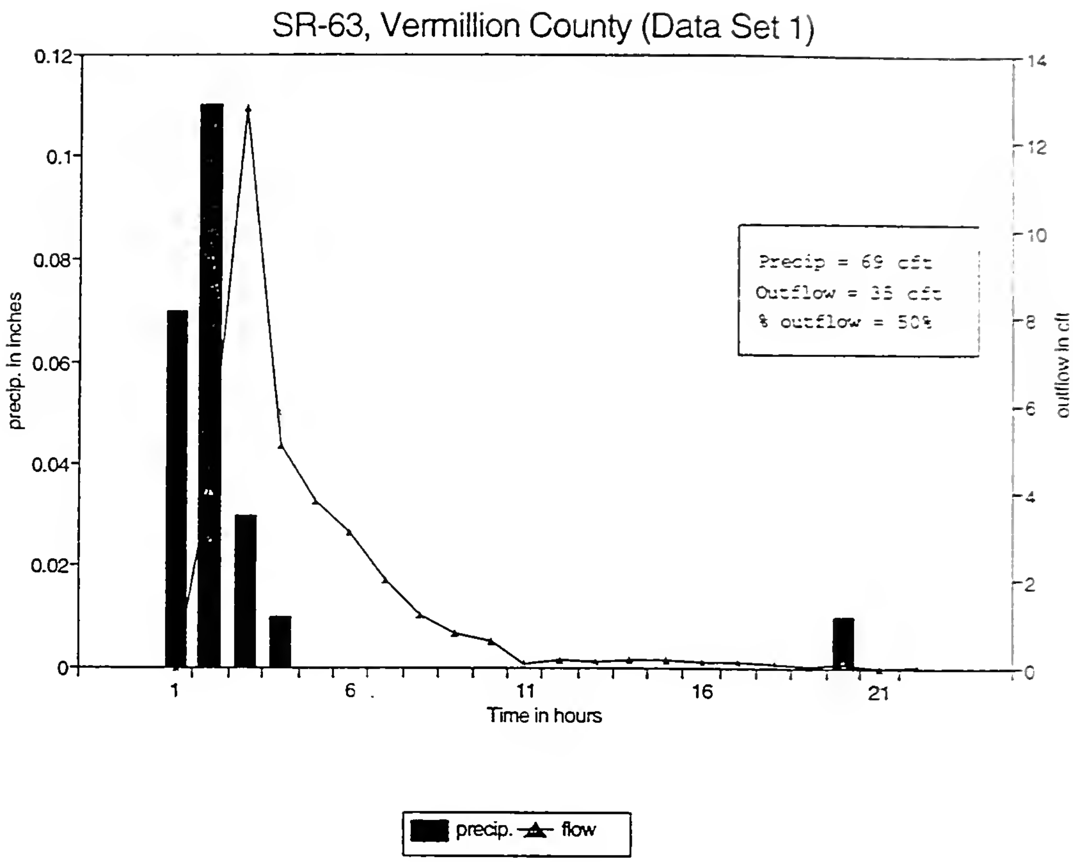


Figure 6.9 Influence of precipitation on outflow volume (SR-63, Vermillion County; Data Set 1)

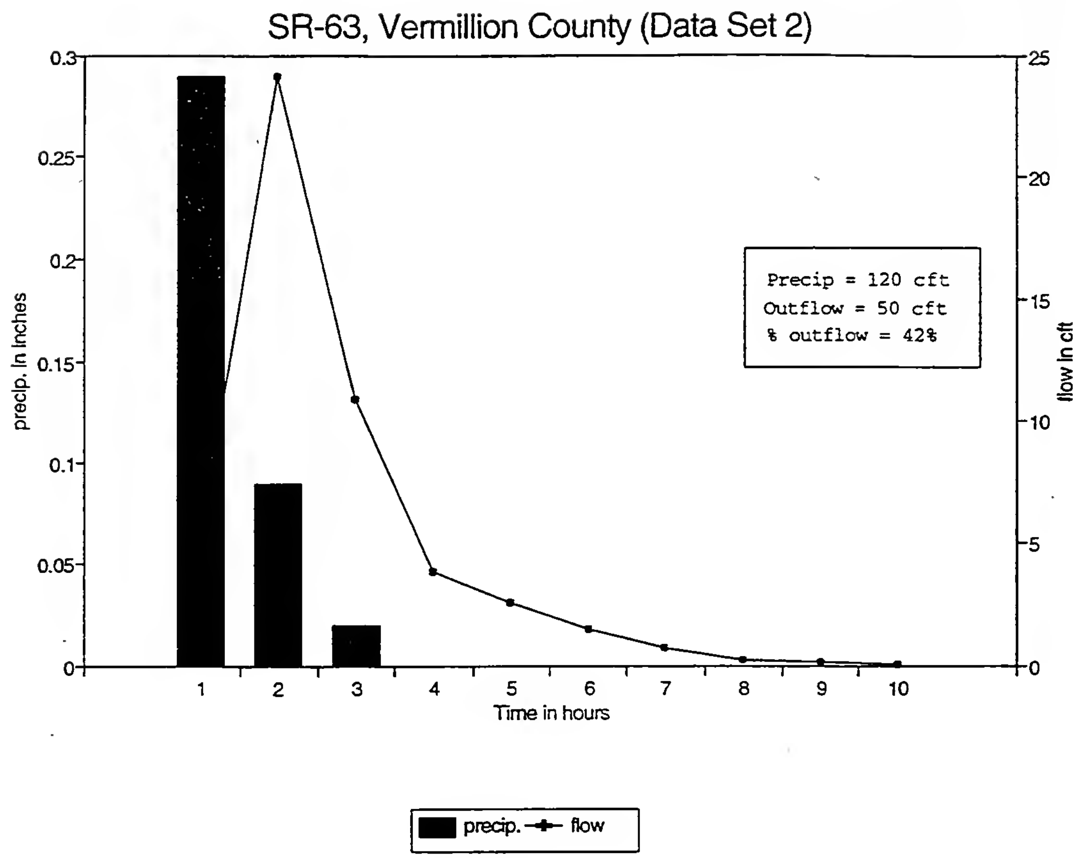


Figure 6.10 Influence of precipitation on outflow volume (SR-63, Vermillion County; Data Set 2)

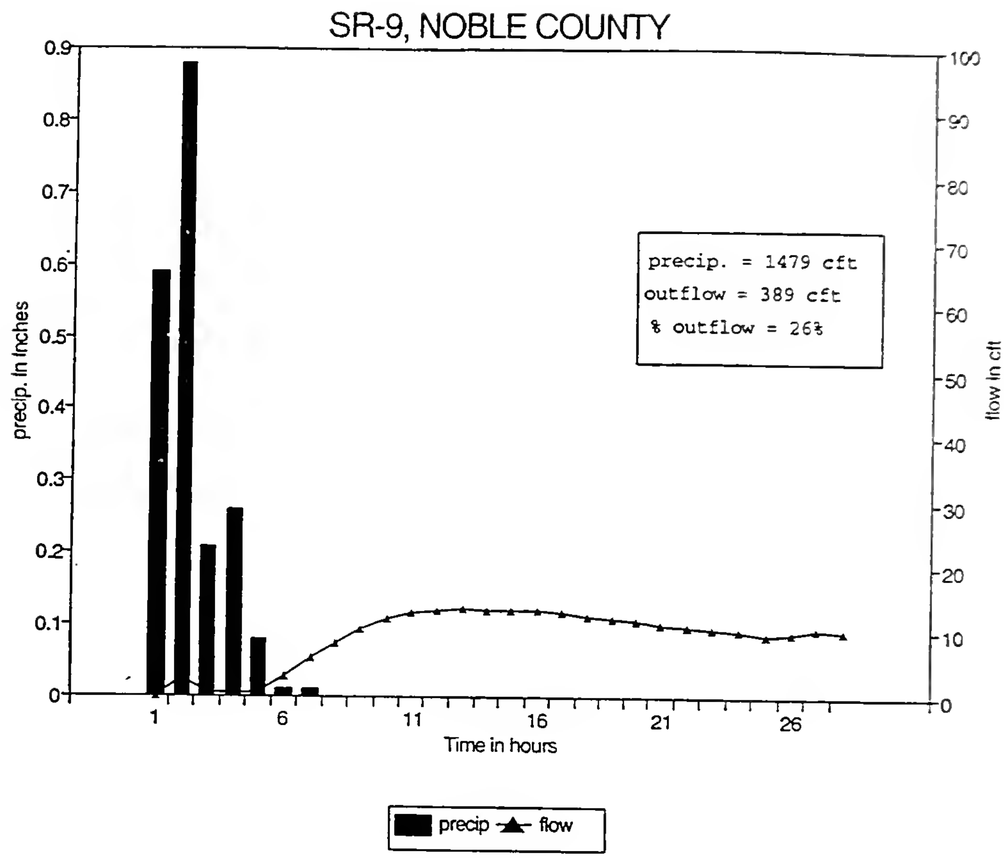


Figure 6.11 Influence of precipitation on outflow volume (SR-9, Noble County; Data Set 1)

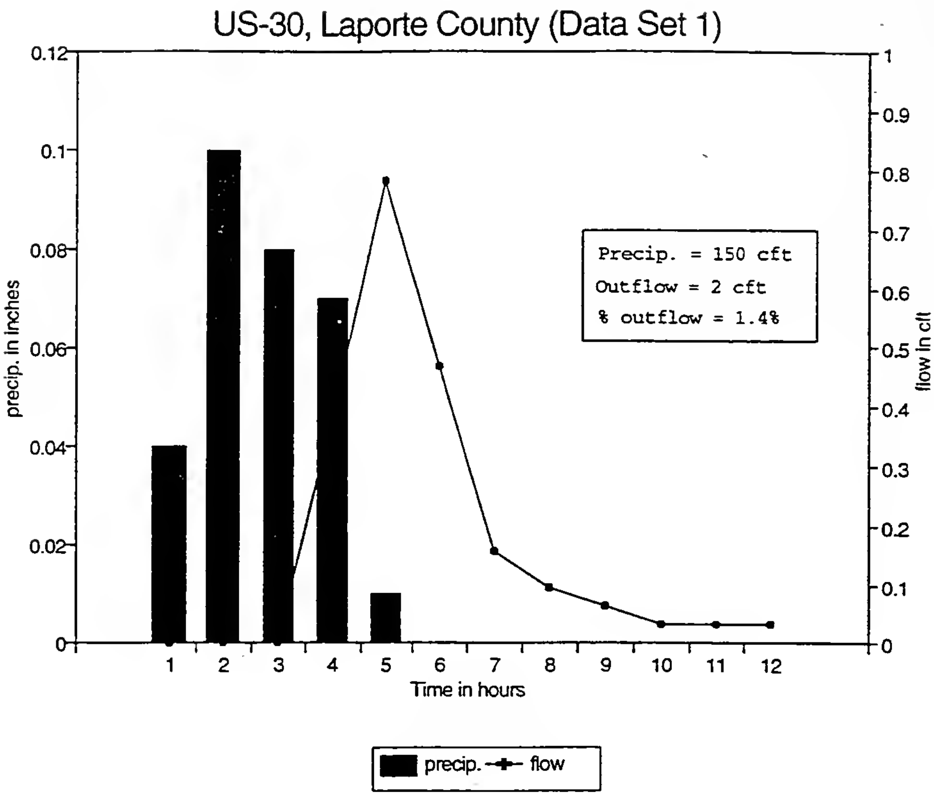


Figure 6.12 Influence of precipitation on outflow volume (US-30, Laporte County; Data Set 1)

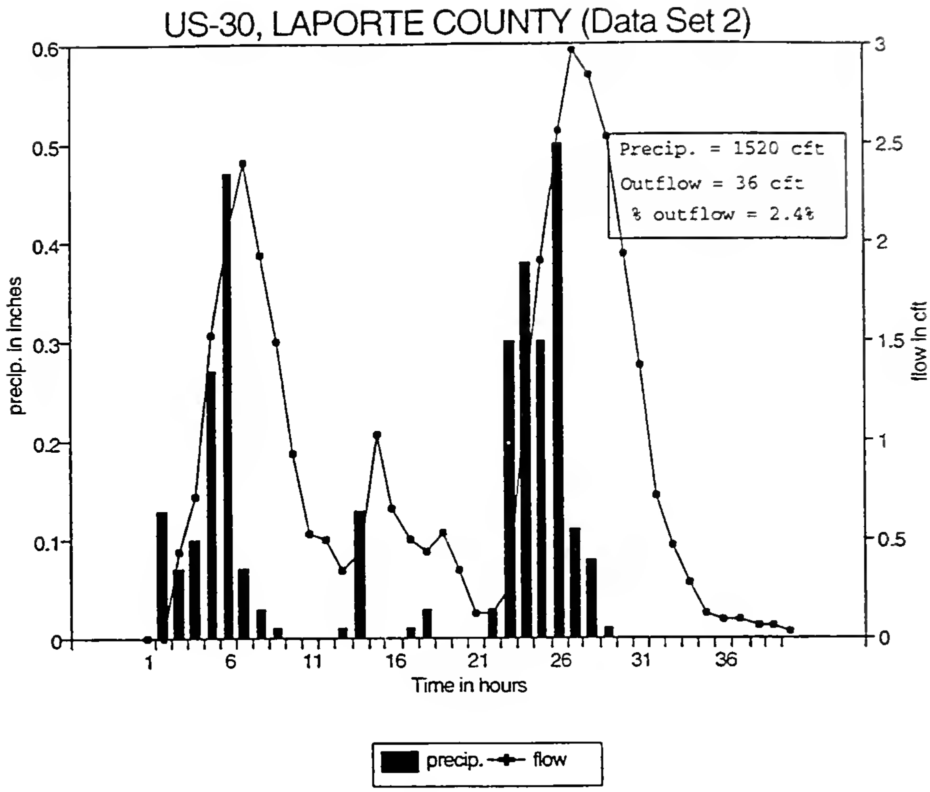


Figure 6.13 Influence of precipitation on outflow volume (US-30, Laporte County; Data Set 3)

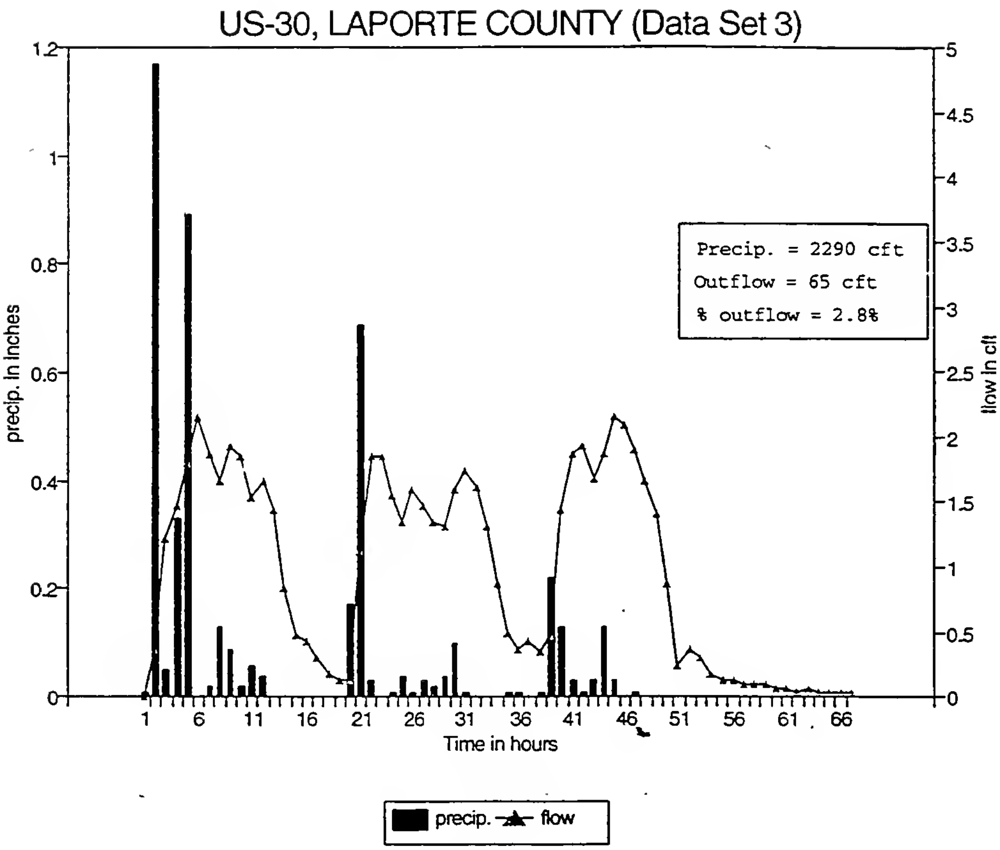


Figure 6.14 Influence of precipitation on outflow volume (US-30, Laporte County; Data Set 3)

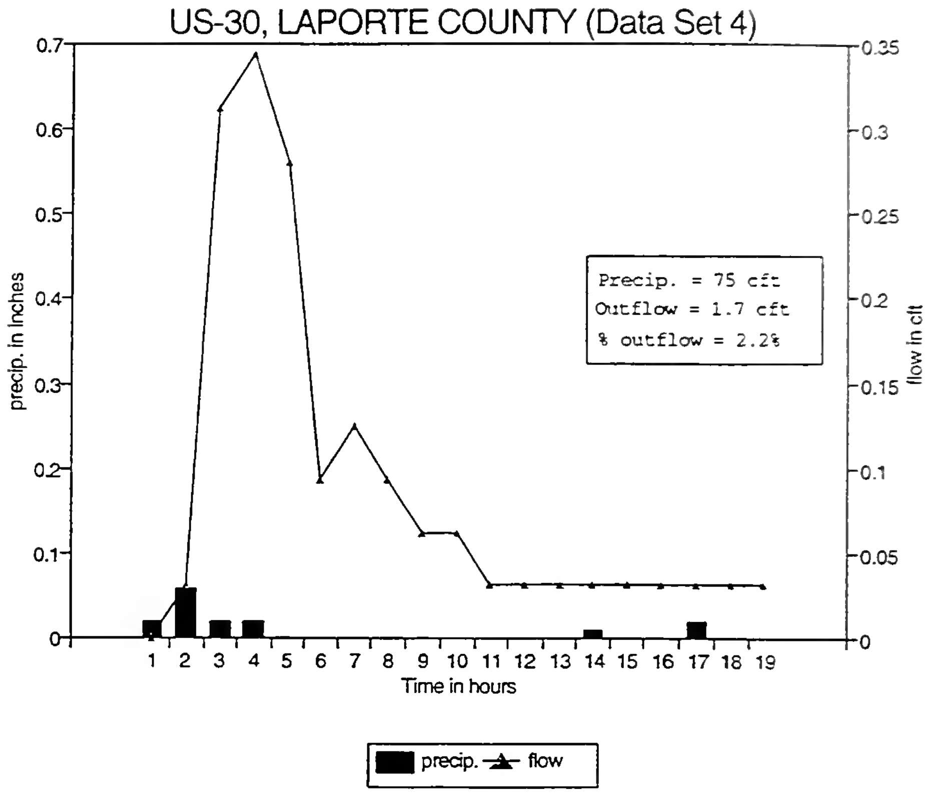


Figure 6.15 Influence of precipitation on outflow volume (US-30, Laporte County; Data Set 4)

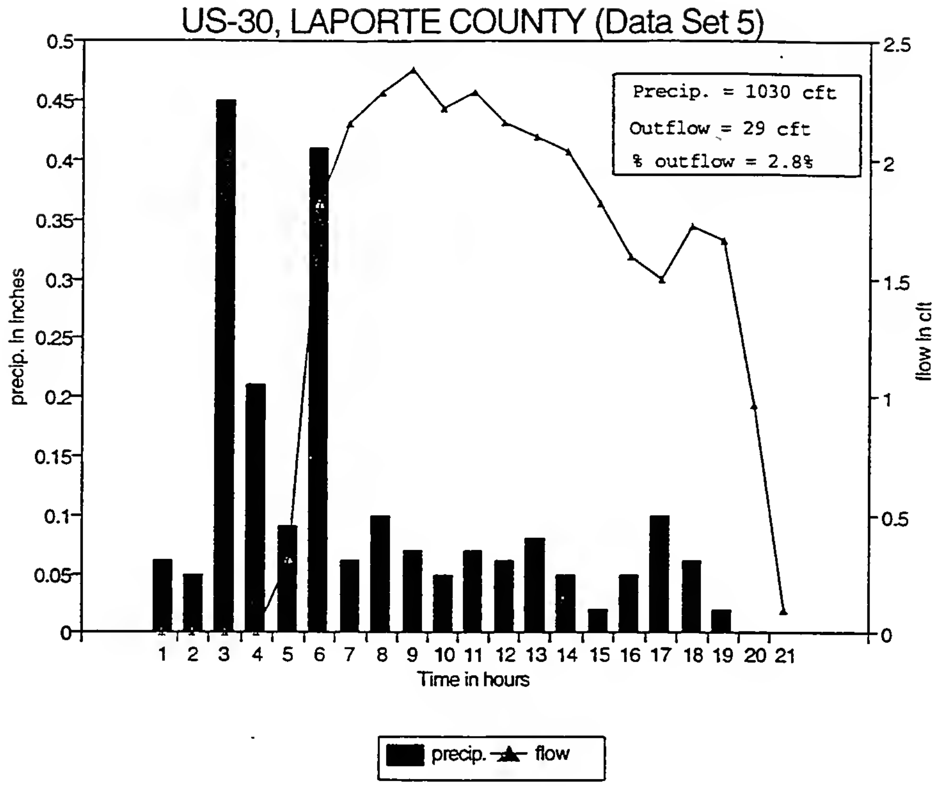


Figure 6.16 Influence of precipitation on outflow volume (US-31, Laporte County; Data Set 5)

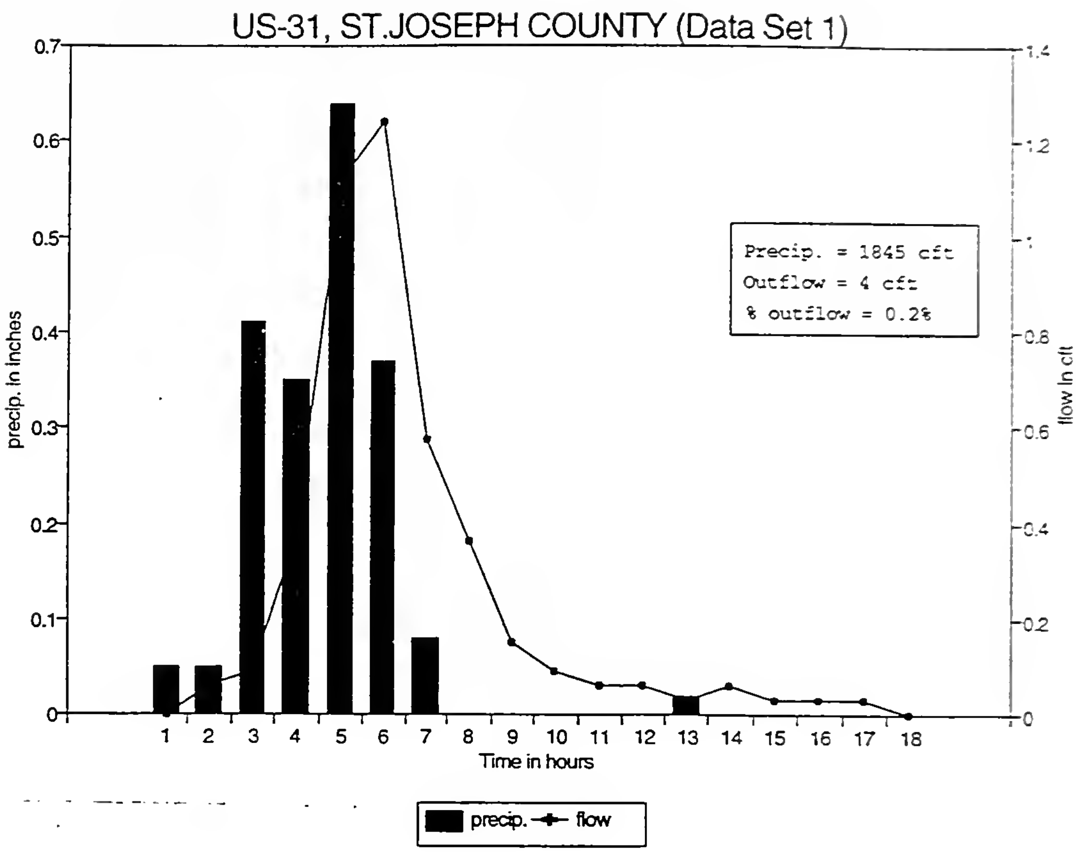


Figure 6.17 Influence of precipitation on outflow volume (US-31, St.Joseph County; Data Set 1)

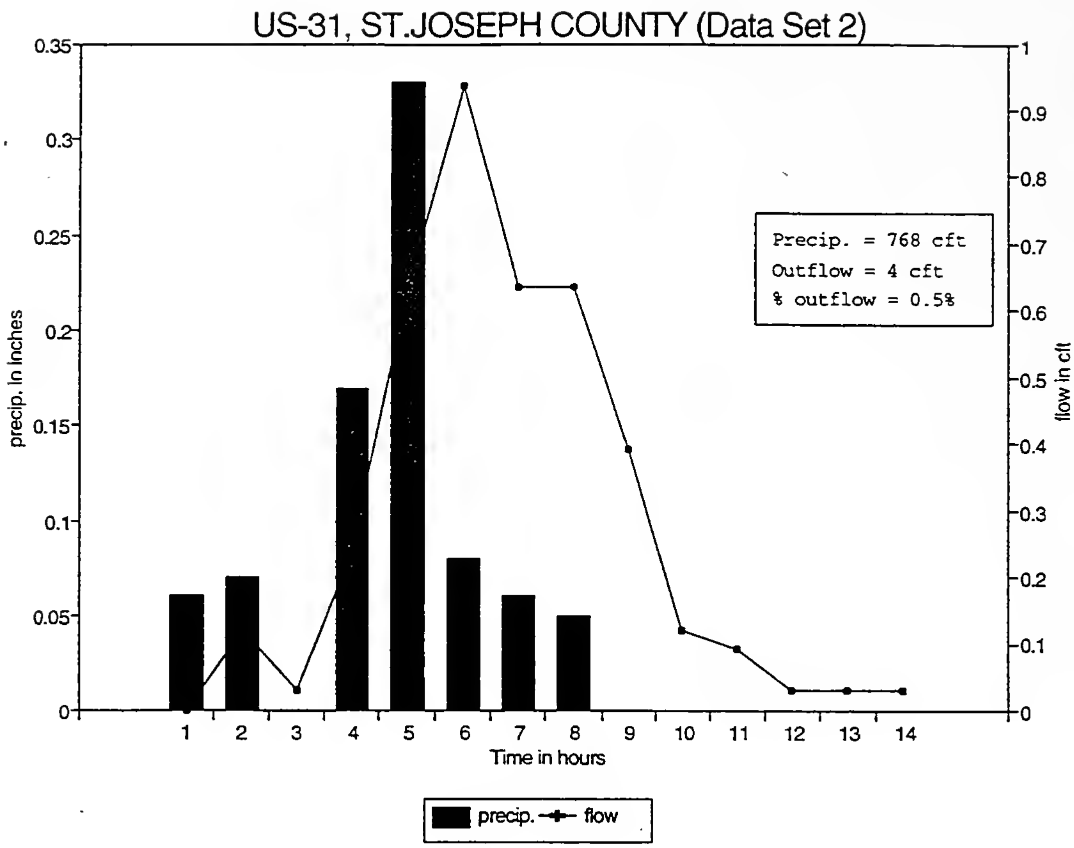


Figure 6.18 Influence of precipitation on outflow volume (US-31, St.Joseph County; Data Set 2)

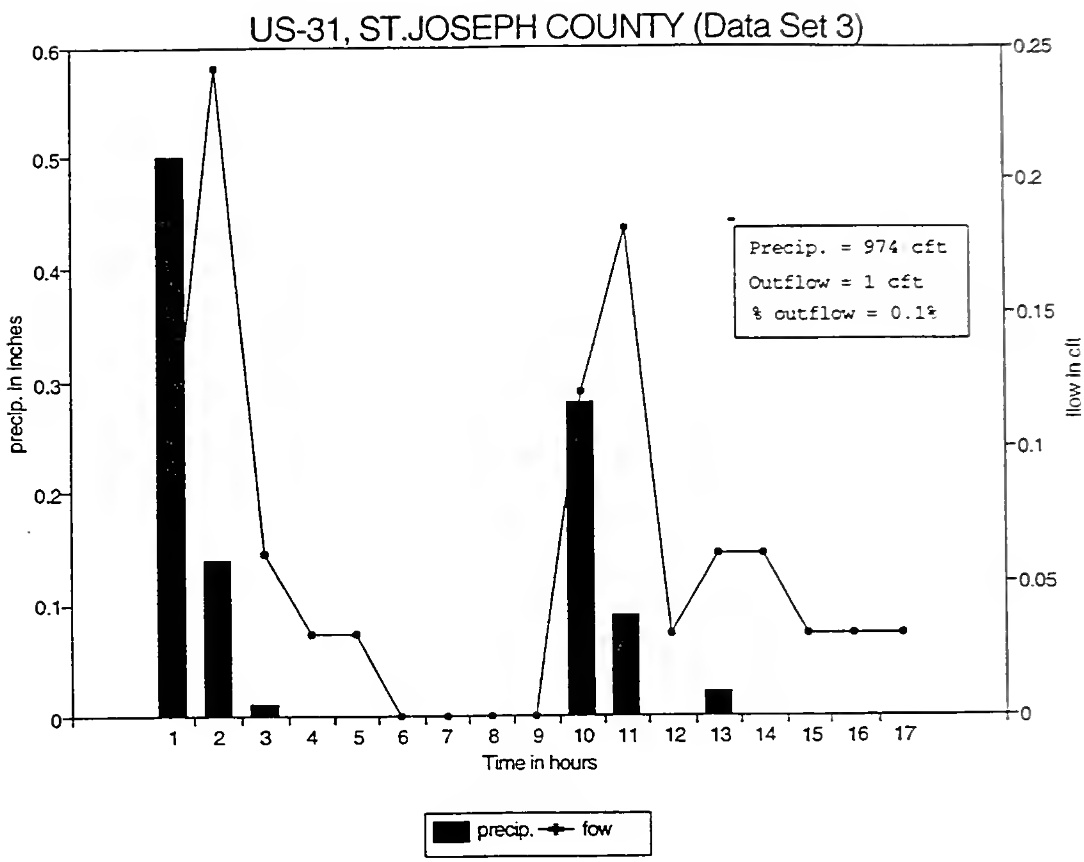


Figure 6.19 Influence of precipitation on outflow volume (US-31, St.Joseph County; Data Set 3)

the subbase layer towards the drain. The rate of flow in turn will depend upon pavement geometry, hydraulic properties of the pavement layers and condition of the edge drains.

A study of Table 6.1 shows high outflow volumes for both concrete and asphalt pavements as compared to overlaid pavements. In fact, the percentage of outflow volume for overlaid pavements is negligible. Overlaid pavement sections 5 and 6, have the same type of edge drains, and the outflow percentage is lower for section 6. The lower permeability of the base layer is considered to be the reason for reduced flow for this section.

Sections 9 and 7 are asphalt pavements with edge drains. However, both outflow response is faster, with outflow percentage higher for section 9. This is attributed to the difference in pavement condition of the two sections. Both sections had edge cracking, but section 9 had higher levels of longitudinal and transverse cracking. The increase in the number of surface cracks would contribute to higher surface infiltration and subsequently higher outflow. For concrete pavements of sections 1, 4 and 10, there is no marked difference in the performance of the subdrainage systems. The minor difference in outflow volumes is attributed to the degree pavements are saturated at the start of a precipitation event. Section 10 incorporating a fin drain also exhibited high outflow volumes. The poor condition of shoulder seal and the presence of an impermeable subgrade would increase the

lateral flow towards the drain.

Field data collected in the current study does not indicate a trend of higher outflow volume with increased rainfall intensity. At most of the sections, a lower intensity of precipitation yielded similar outflow volumes. For concrete pavements, the percentage outflow from edge drains are between 0.05 and 0.70. For asphalt pavements, the ouflow percentage lies between 0.26 and 0.50. For overlaid pavements, the outflow percentage is still lower. Outflow data shows, that the concept of pavement subsurface drainage criteria based on design precipitation rates only (Cedergren, 1973) is conservative. The actual infiltration of water is a complex phenomenon. Pavement type and condition, edge drain type and layer properties have an effect on the amount of water entering and exiting a pavement.

Statistical Analysis

In an effort to determine the effect of precipitation and pavement factors on outflow volume, a statistical analysis was conducted using the method of least squares as outlined in the SAS General Linear Models (GLM) procedure (SAS Institute, 1985). The GLM procedure was used because of missing and unequal number of observations for the different combinations of pavement and edge drain types. For example, there is no combination existing for some of the levels, as fin drains are not used with full depth asphalt pavements in Indiana. For some sites, data from only a single precipitation event was

recorded because of instrument malfunction.

Pavement and edge drain types were considered as class variables. Three pavement types: asphalt, concrete and composite pavements, were included. Pipe and fin drains comprise the two qualitative levels of edge drains. The response variable is the ratio of outflow to precipitation volume expressed as a percentage. Permeability of the base/subbase layer was included in the model as a covariate for increased precision in determining the effects of pavement and edge drain types on the outflow volume. Logarithmic transformation of the response data was carried out to achieve normality. The resulting definition matrix is shown in Table 6.2.

Analysis of covariance technique was used to reduce the error term variability and make the statistical analysis more robust for comparing pavement and edge drain effects. The analysis of co-variance model based on the above design is expressed as:

$$Y_{ijk} = \mu.. + \alpha_i + \beta_j + \gamma(X_{ijk} - X...) + \epsilon_{ijk} \qquad 6.1$$

where:
- Y_{ijk} = value of the response variable (%outflow)
- $\mu..$ = constant
- α_i = main effect of pavement type at i^{th} level
- β_j = main effect of drain type at j^{th} level
- γ = regression coefficient for relation between Y and X
- X_{ijk} = regressor observations assumed as constants
- $X..$ = overall mean
- ϵ_{ijk} = the experimental error; independent $N(0,\sigma^2)$
- $i = 1..3;\ j = 1,2;\ k = 1..18$

The GLM procedure was run in two stages. In the first stage, the regressor variable was not included. The

Table 6.2 Definition Matrix for Statistical Analysis

Factor A (Pavement Type)	Factor B (Drain Type)			
	Pipe Edge Drain (j=1)		Fin Drain (j=2)	
	% outflow (Y)	base perm. (X)	% outflow (Y)	base perm. (X)
Concrete i=1	5.53 40.40 26.52 69.82 32.12 33.83	0.6 0.6 0.6 0.6 0.6 0.6	59.92 34.63	74 74
Asphalt i=2	50.64 41.72 26.31	0.12 0.12 0.12	*	*
Overlay i=3	*	*	1.35 2.40 2.84 2.21 2.82 0.24 0.51 0.10	1.2 1.2 1.2 1.2 1.2 0.12 0.12 0.12

* combination does not exist

resulting analysis showed the pavement type to be significant at 95% confidence interval (α=0.05) with an F-value of 11.74, whereas the edge drain type was insignificant. The goodness of fit value was 0.79. In the second run, base permeability was included as a regressor variable. The corresponding analysis showed base permeability in addition to pavement and edge drain types to be significant at 95% confidence interval. The goodness of fit value in this case was 0.92. Table 6.3 shows the correponding F-values for pavement type, edge drain and base permeability. Appendix G contains the statistical input and output files for the SAS program.

The statistical analysis confirms and complements the engineering analysis described earlier. There is a significant effect of pavement and edge drain types on the amount of water being removed from a pavement system. It is an accepted fact that higher base permeabilities result in less water being trapped in the pavement subsystems for extended periods of time. The statistical significance of base permeability on percentage of water coming out of the pavement system reinforces this issue.

Moisture Variation Below Pavements

Results of instrumentation yielded considerable data on piezometric head variation and suction changes in pavement subbases and subgrades. At some sites, reduced numbers of sensors and poor performance of soil moisture blocks resulted

Table 6.3 Analysis of Variance for Experimental Design

Case 1: Without Regressor Variable

Source	DF	TypeIII SS	Mean Square	F-Value	Pr>F
PVMT	2	4.57029000	2.28514500	11.74	0.0009
DRAIN	1	0.07150417	0.07150417	0.37	0.5536

Case 2: With Base Permeability as Regressor Variable

Source	DF	TypeIII SS	Mean Square	F-value	Pr>F
PVMT	2	1.79637403	0.89818702	11.48	0.0011
DRAIN	1	1.81297567	1.81297567	23.18	0.0003
BASEK	1	1.82533333	1.82533333	23.33	0.0003

in missing or erratic data. Analysis of moisture variation is restricted to reasonable data sets.

Piezometric Head Variation

Figures 6.20 to 6.29 show piezometric head variation in subbase layers for the instrumented sites. All sections show similar trend of head buildup immediately after a precipitation event. The immediate response can be partly attributed to the condition of the core holes. After placement of sensors, the cores were backfilled with pea gravel and topped with asphalt mix. The discontinuity of pavement and patch materials resulted in water infiltrating into the core holes through the cracks. Additional sources of intrusion were surface cracks and pavement-shoulder joint openings.

A comparison of head buildups in Sections 1 and 3 shows a constant pressure head at the subbase level for a considerable period of time at Section 3, whereas it gradually decreases at Section 1. Both sections are concrete pavements and have identical subbases. The prolonged head buildup at Section 3 can be attributed to a number of factors. The section was in a cut and did not have an edge drain. The base was not daylighted. The subgrade permeability was very low and prevented vertical migration of moisture. Thus water was trapped in the subbase layer resulting in pore pressure buildup. The pressure head was confirmed by the presence of moisture when the sensors were removed from Section 3.

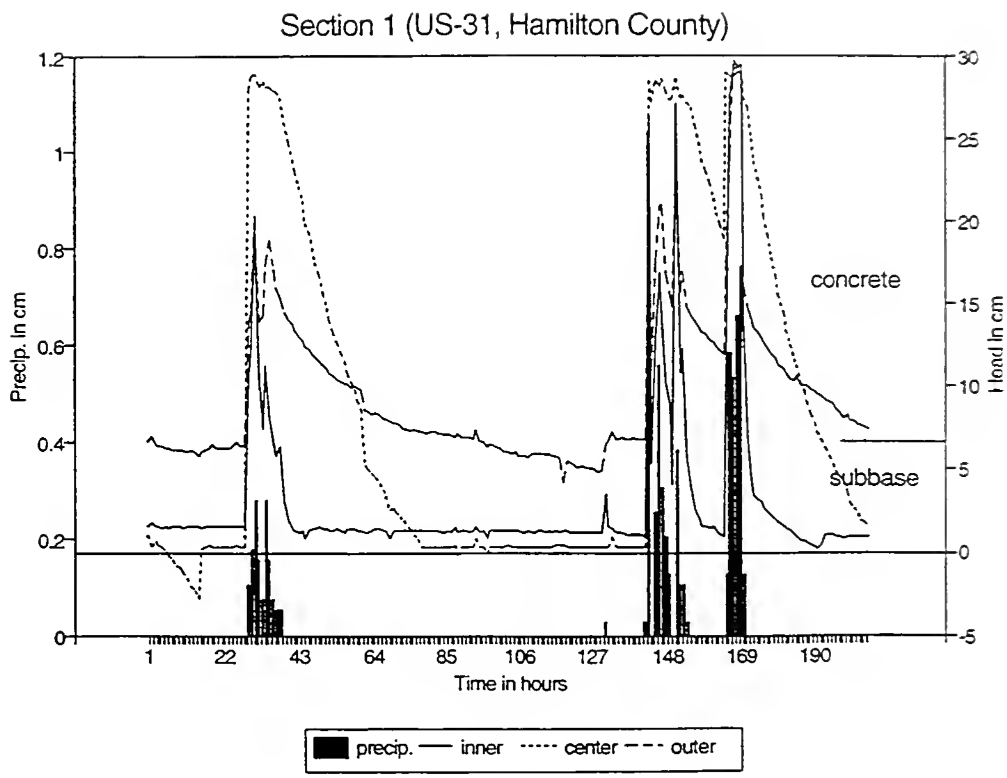


Figure 6.20 Piezometric head variation in subbase (Section 1)

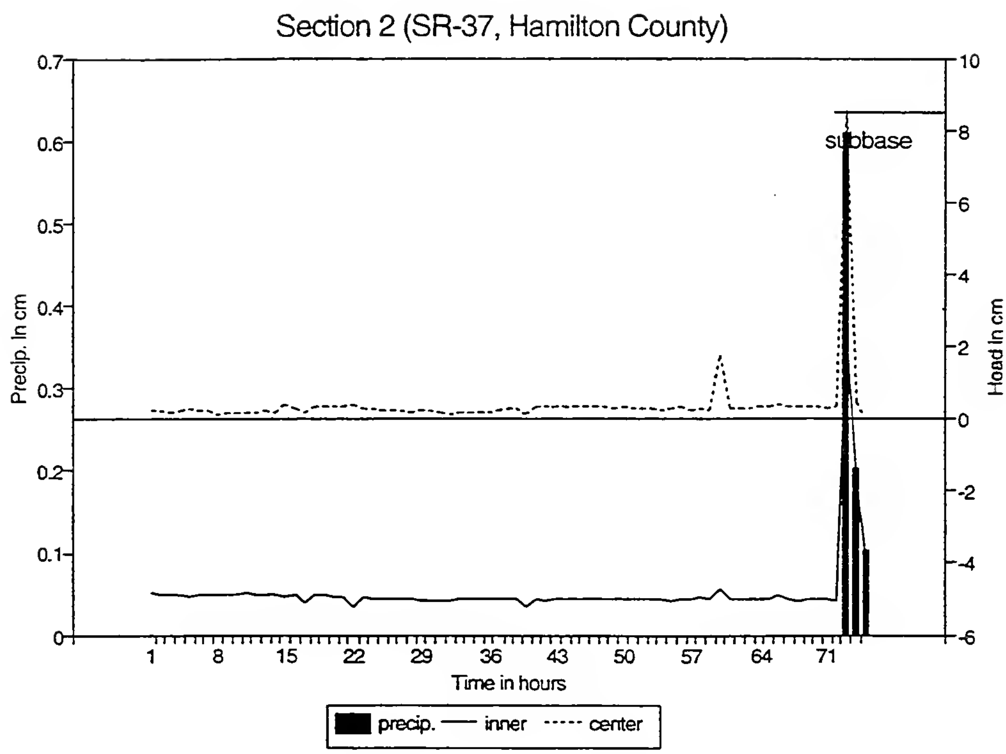


Figure 6.21 Piezometric head variation in subbase (Section 2)

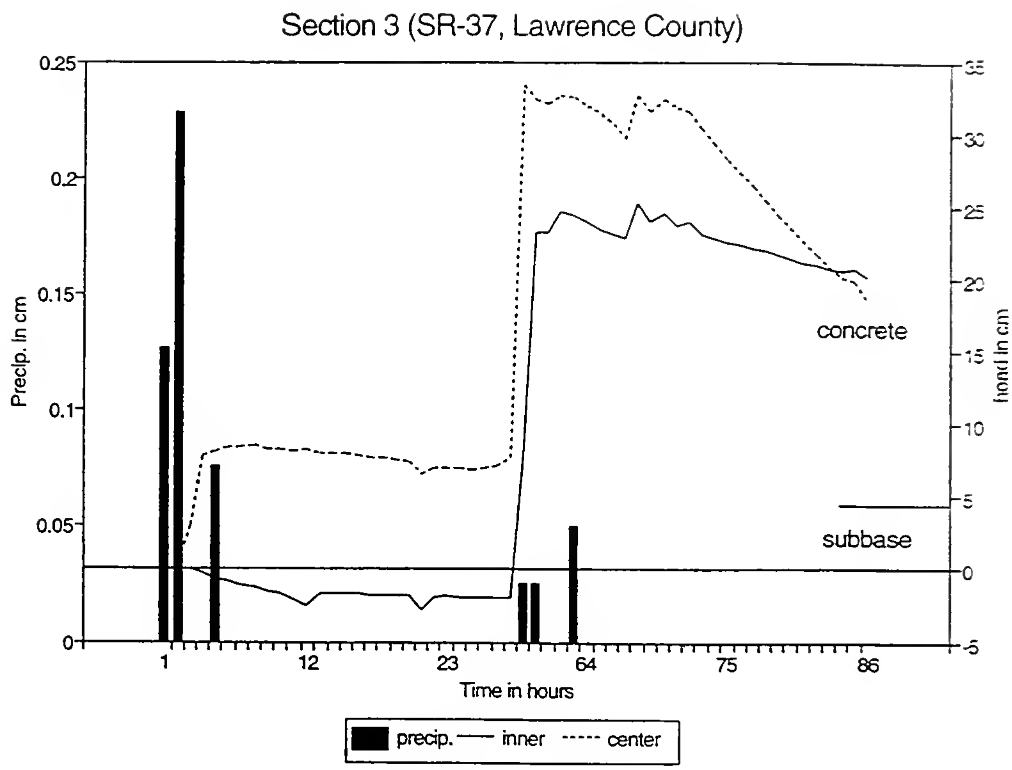


Figure 6.22 Piezometric head variation in subbase (Section 3)

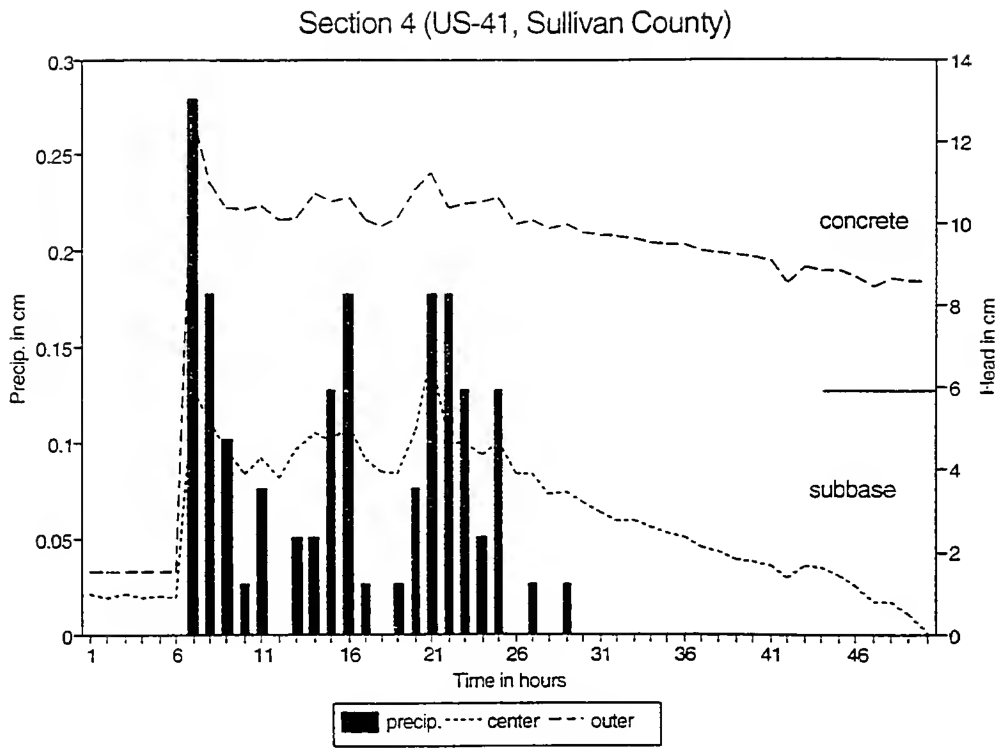


Figure 6.23 Piezometric head variation in subbase (Section 4)

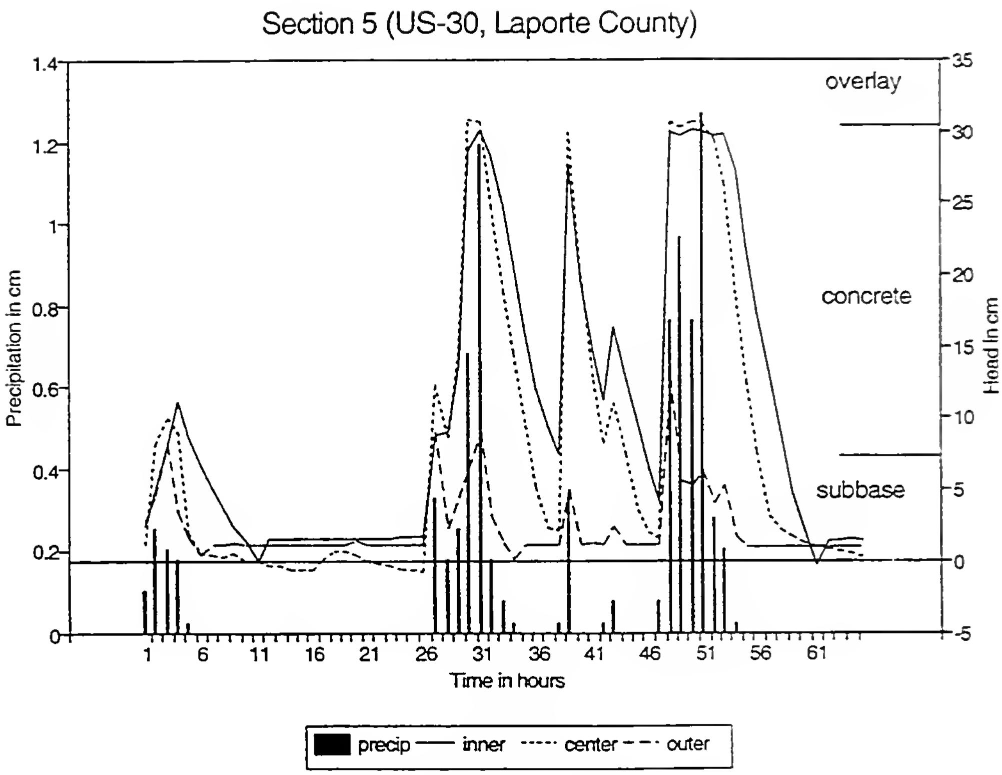


Figure 6.24 Piezometric head variation in subbase (Section 5)

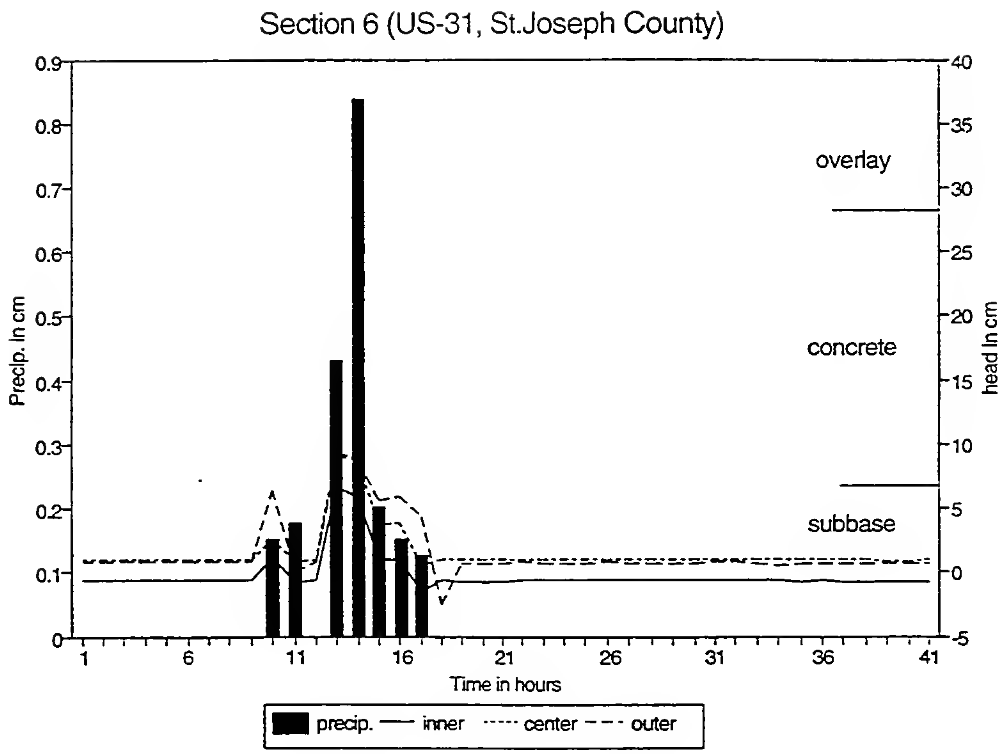


Figure 6.25 Piezometric head variation in subbase (Section 6)

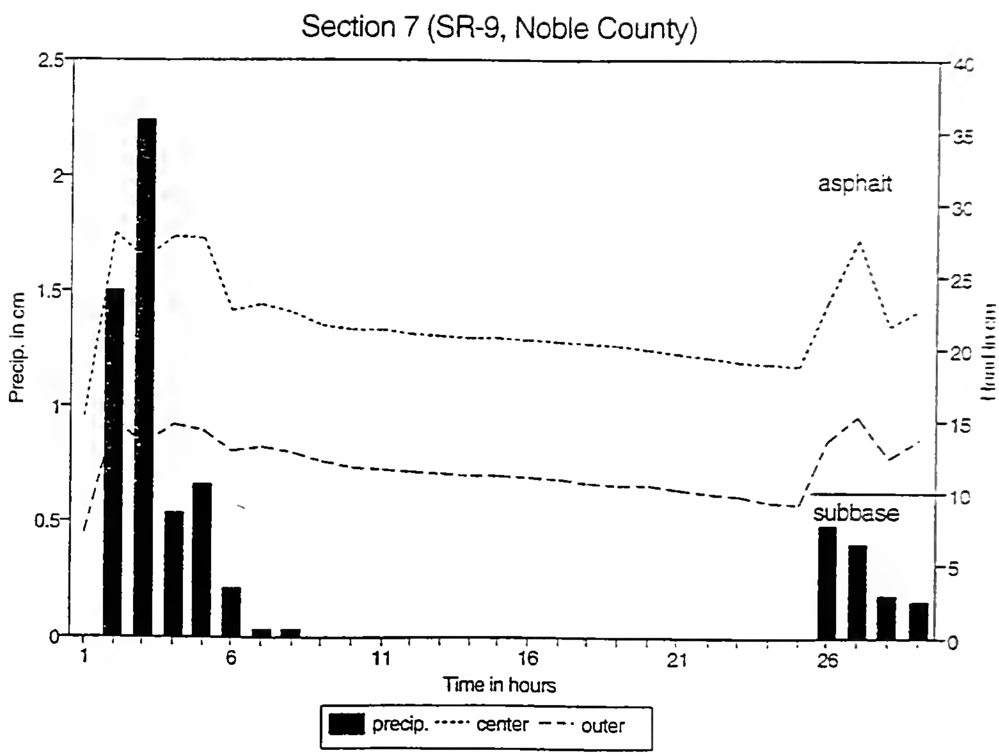


Figure 6.26 Piezometric head variation in subbase (Section 7)

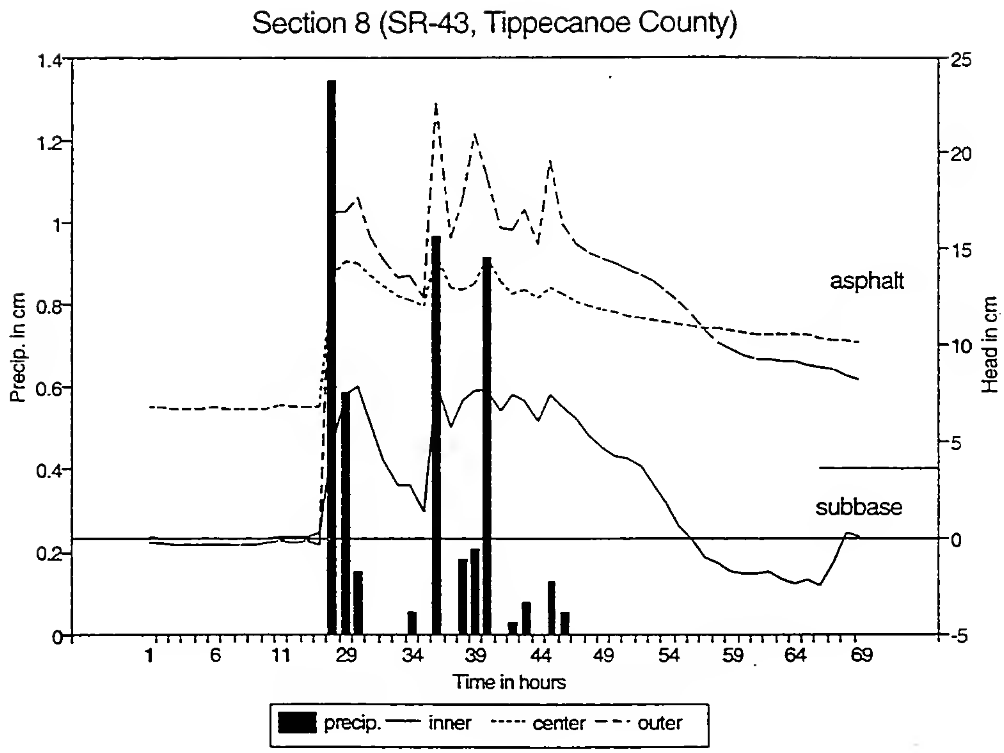


Figure 6.27 Piezometric head variation in subbase (Section 8)

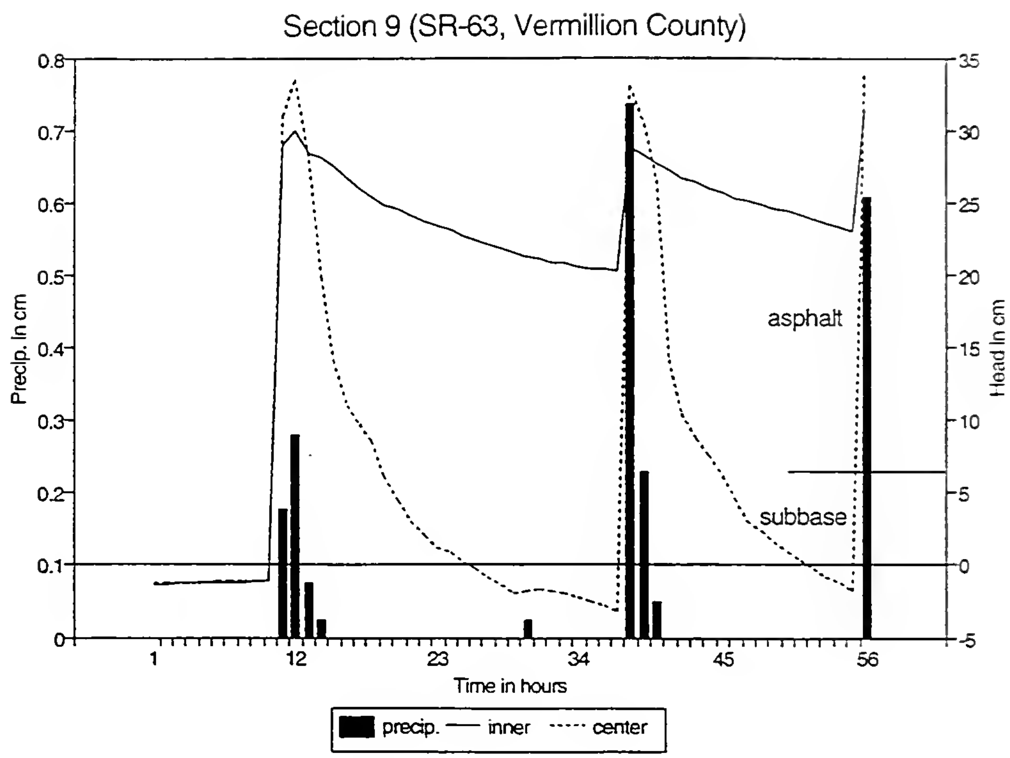


Figure 6.28 Piezometric head variation in subbase (Section 9)

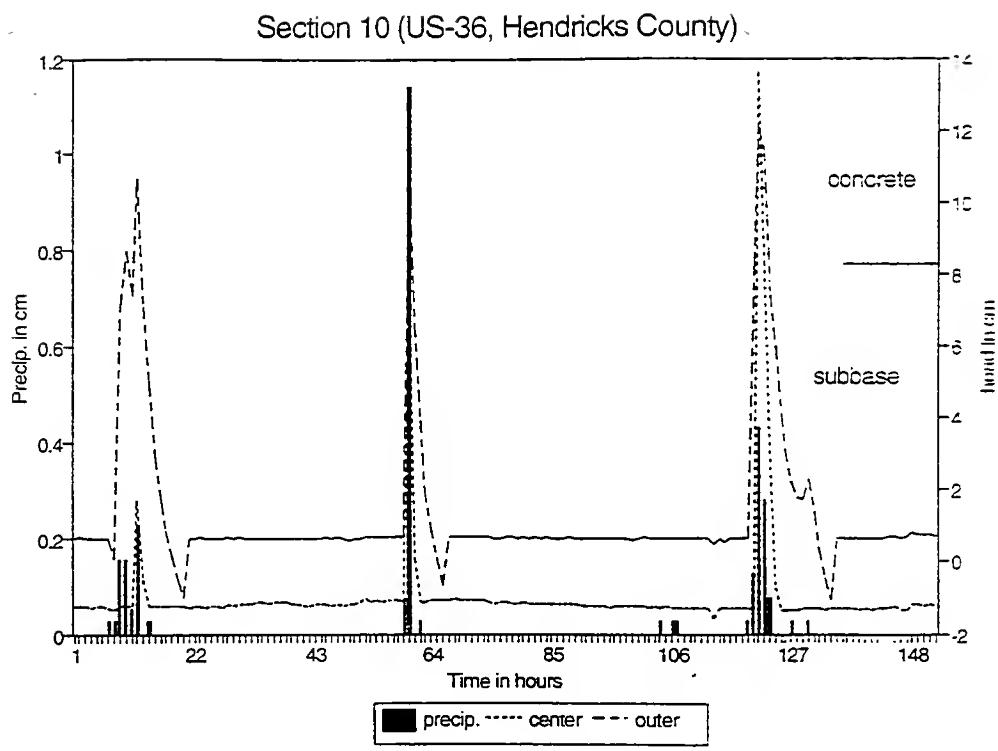


Figure 6.29 Piezometric head variation in subbase (Section 10)

Section 2, an asphalt pavement with a large stone aggregate subbase, did not indicate significant head variation. The top size of aggregate for the subbase was found to be 2 inches. It is likely that the open graded nature of the subbase resulted in rapid removal of water from the pavement system and consequently low piezometric head.

Significant head buildup was recorded in sections 4 and 10, which are concrete pavements having different edge drain types. The piezometric head dissipates much slower at section 4 having a fin drain as compared to section 10, which has a pipe edge drain. This is apparently due to the higher flow capacity of pipe edge drains.

Sections 5 and 6, which are overlaid pavements incorporating fin drains do not indicate a substantial variation in head. The slightly higher head at Section 5 is believed to be related to the higher precipitation intensity during data collection. Once rainfall ceased, there was an immediate drop in the head. Both sites have sandy subgrade, which allows for vertical movement of infiltrated water at these sites. This also accounts for the low outflow volumes recorded at these sites.

A high intensity precipitation event was recorded within a 24 hour period. The constant nature of piezometric head at this site is attributed to the presence of groundwater. Each precipitation event produced an immediate rise in groundwater elevation. Additional moisture resulted in the drainage

capacity of the edge drain being exceeded. As a result, moisture is retained in the subbase and causes head buildup.

Section 8 is an asphalt section with an unsealed aggregate shoulder and without edge drains. Piezometric head variation is not significant at this site. It is believed that the positive surface drainage (site is adjacent to the Wabash River) and the aggregate shoulder contributes to minimal head buildup.

A study of the figures indicates that piezometric head across a section varies. For a majority of the instrumented sections. The area around the lane center showed the highest head buildup as compared to the wheel paths. This could be attributed to the flowpath of moisture within the subbase layer. The source of entry for water is at the inner and outer pavement edges. When the drainage capacity is exceeded, additional moisture infiltration results in the formation of a perched water table in the subbase. The crest of the piezometric surface is believed to be formed within an area around the lane center.

For Section 9, densification indicated by rutting has led to reduced permeability and is believed to be responsible for a prolonged head buildup.

Only limited data was obtained for subgrade moisture variations because of transducer malfunctions. Figures 6.30 to 6.35 show piezometric head variations in the subgrade at six sites. The figures indicate a rise in pressure head

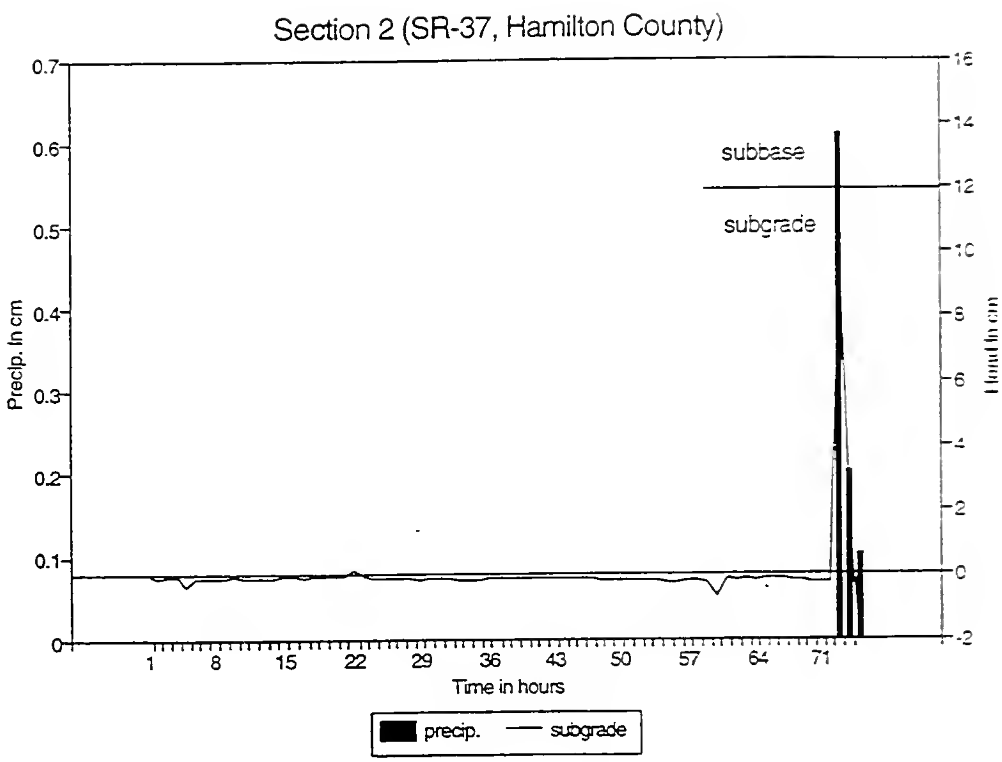


Figure 6.30 Influence of precipitation on subgrade (Section 2)

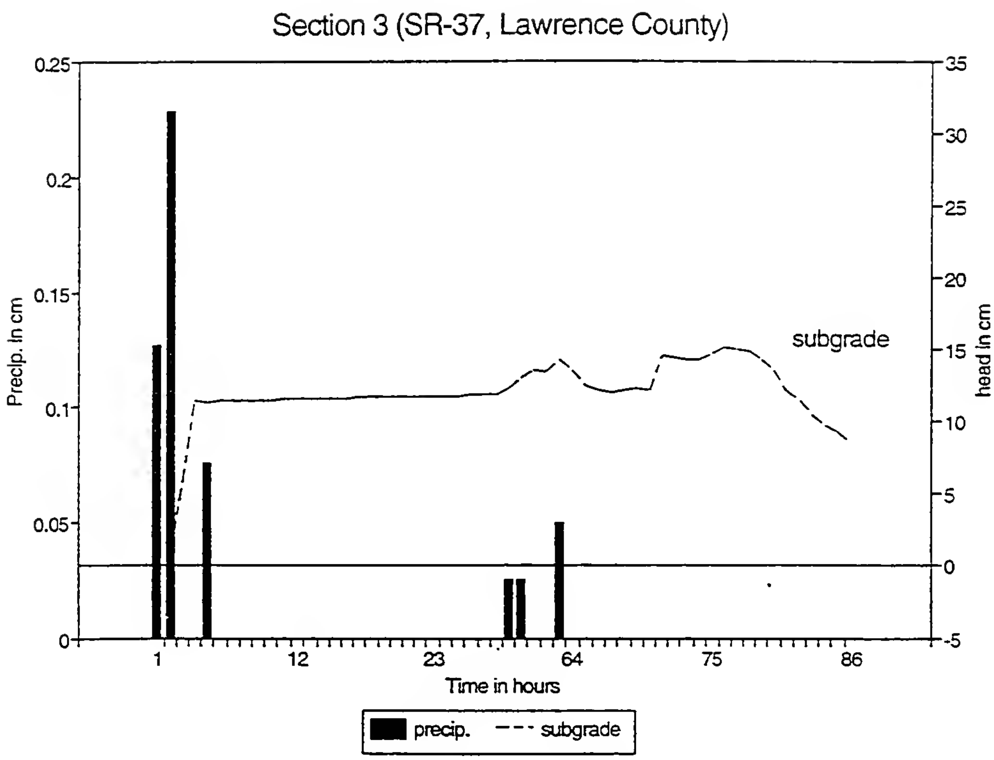


Figure 6.31 Piezometric head variation in subgrade (Section 3)

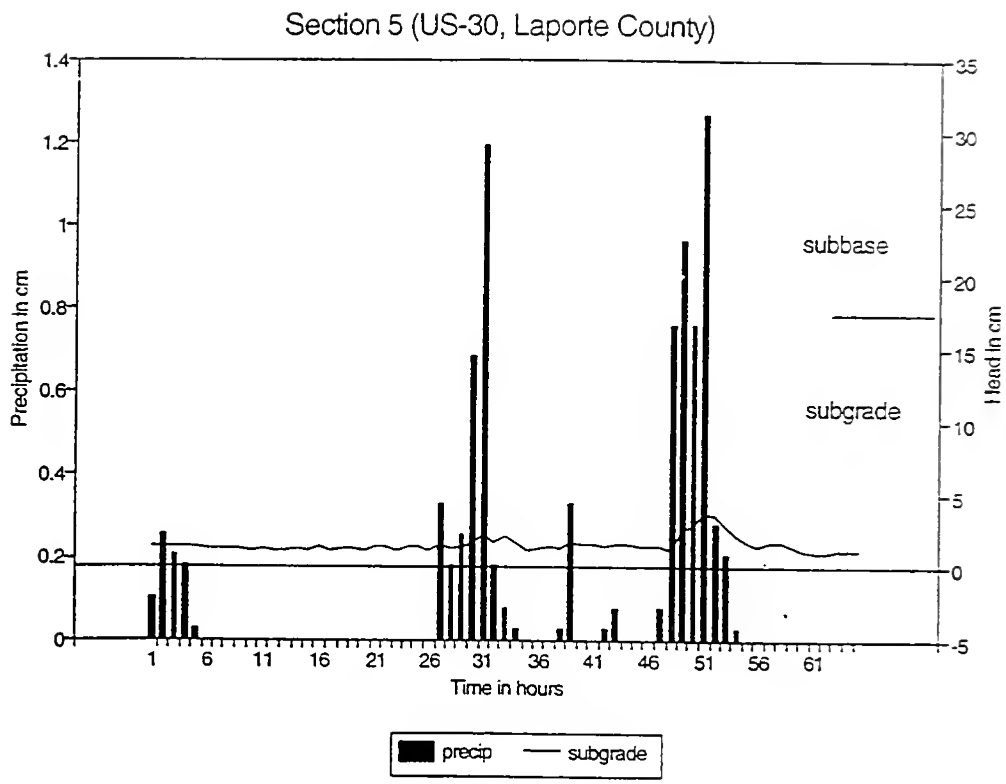


Figure 6.32 Piezometric head variation in subgrade (Section 5)

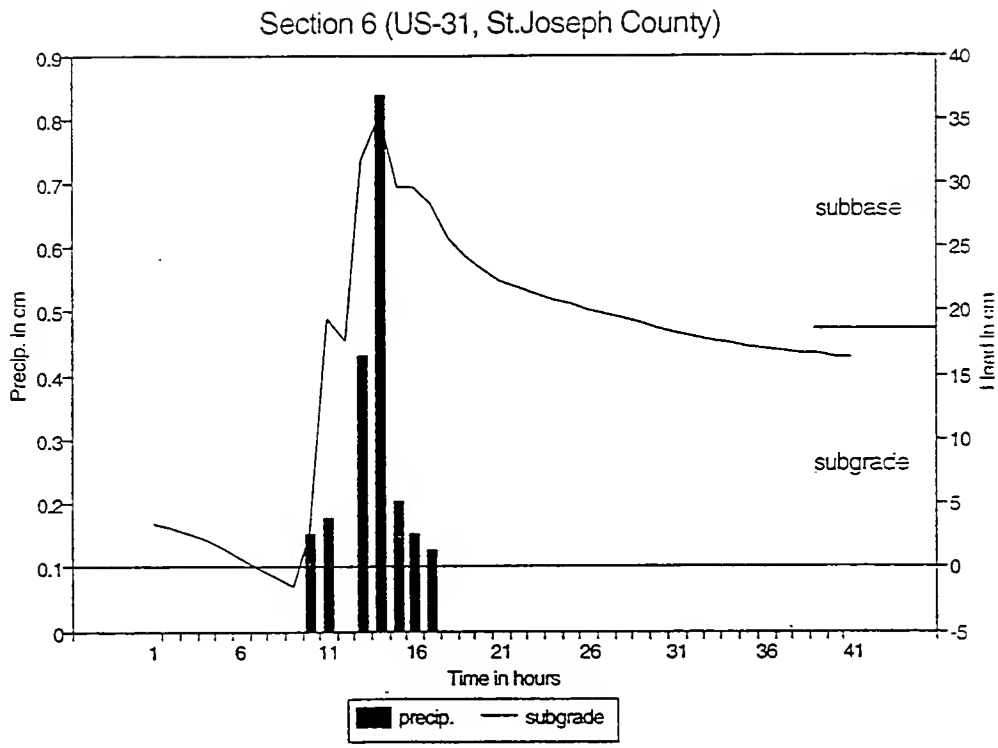


Figure 6.33 Piezometric head variation in subgrade (Section 6)

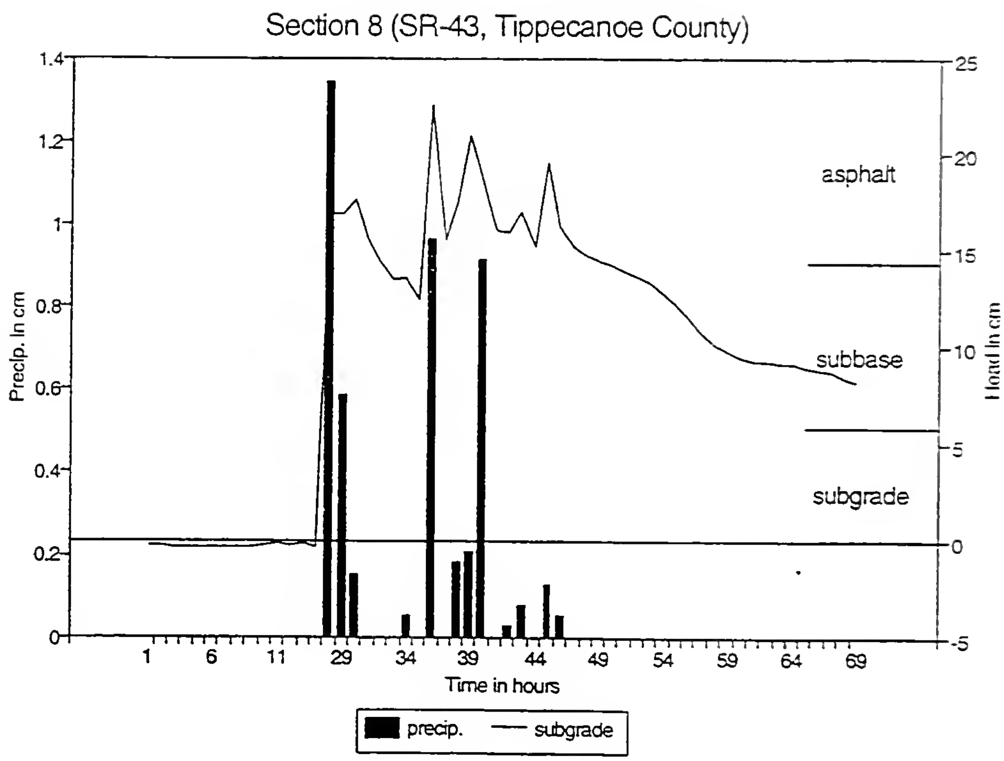


Figure 6.34 Piezometric head variation in subgrade (Section 8)

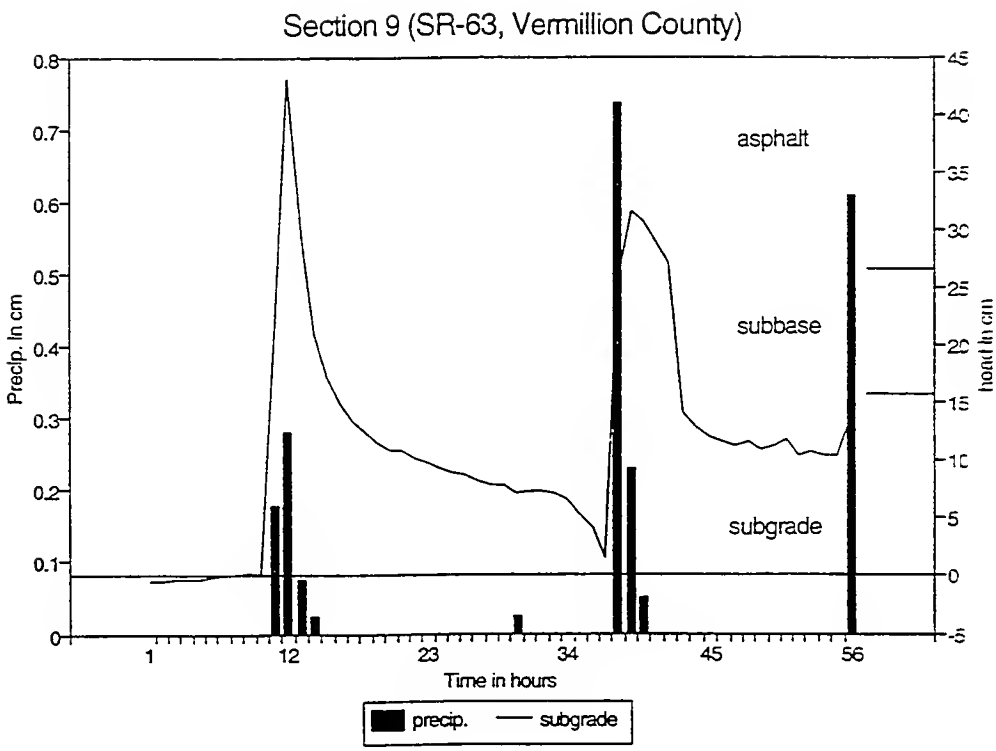


Figure 6.35 Piezometric head variation in subgrade (Section 9)

immediately following a precipitation event. The head then continues to dissipate typically over a period of 24 hours. The maximum head in the subgrade at the test sites did not increase beyond the subbase-subgrade interface. This suggests that most of the head buildup in the subbase layers is due to the development of a perched water table. The low pore pressures in the subgrade would not be expected to promote intrusion of fines into the subbase.

Moisture Tension Variation

Moisture tension variation at test sites measured with the gypsum blocks is shown in Figures 6.36 to 6.40. As described in Chapter 4, erratic suction were recorded at most of the sites due to poor block performance. Only data from the test sites where consistent data was achieved is shown in the figures.

As the soil becomes saturated from surface infiltration, its moisture content increases with a corresponding decrease in suction. Once precipitation ceases and with drainage, suction values tend to increase. Analysis of results from the test sites are in agreement with this concept. A study of the suction-moisture characteristics of subbase and subgrade soils (Appendix D) shows that moisture content changes associated with corresponding suction variation is insignificant.

Moisture variations in pavement layers do not indicate a specific trend. This is due to the short time period in which

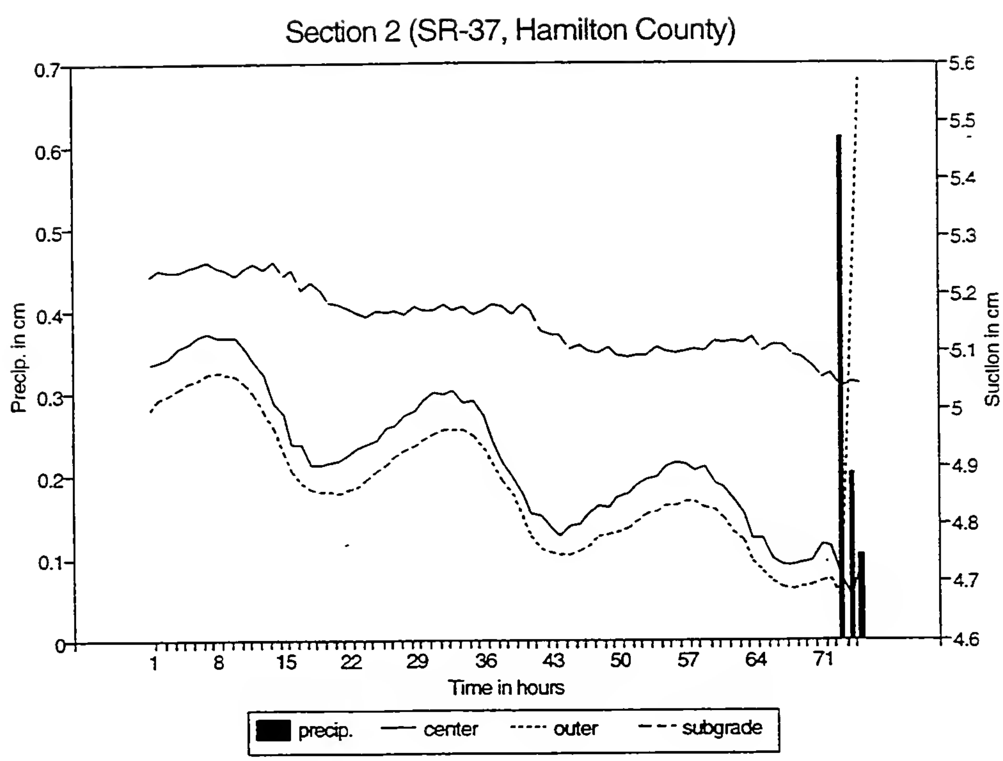


Figure 6.36 Suction variation in Section 2

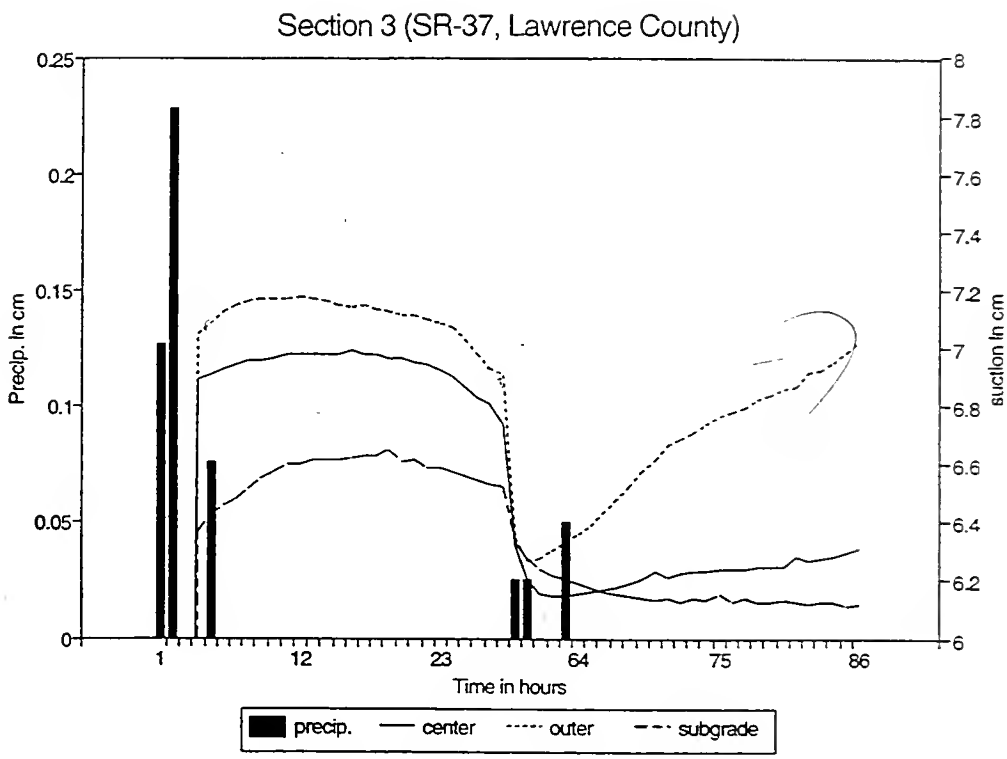


Figure 6.37 Suction variation in Section 3

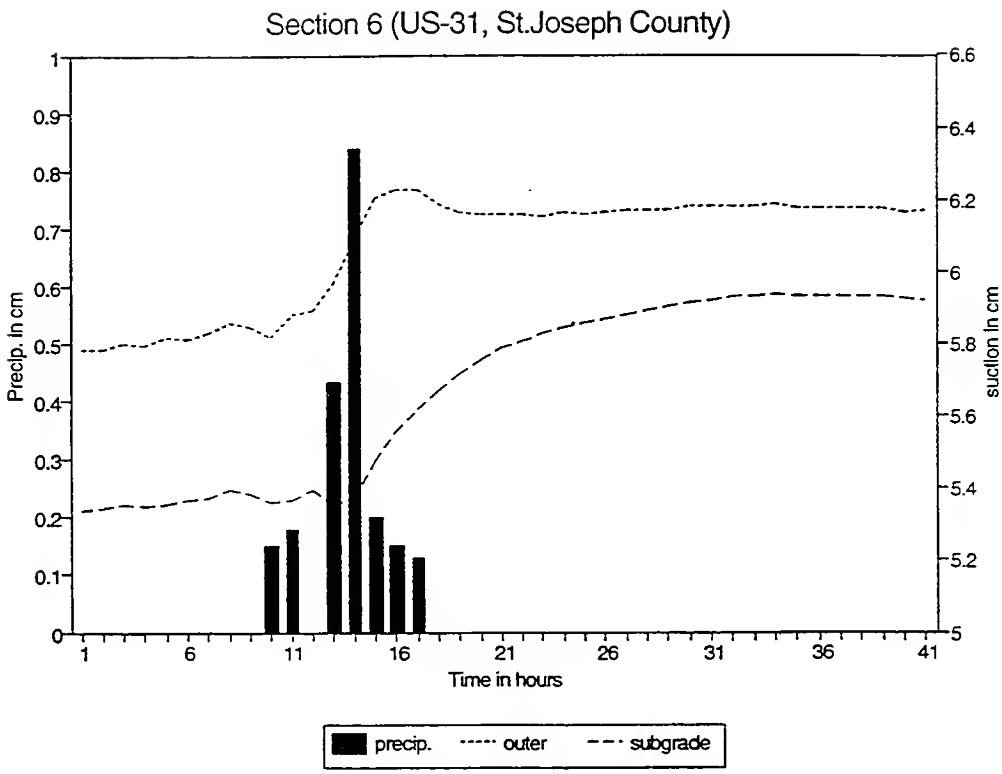
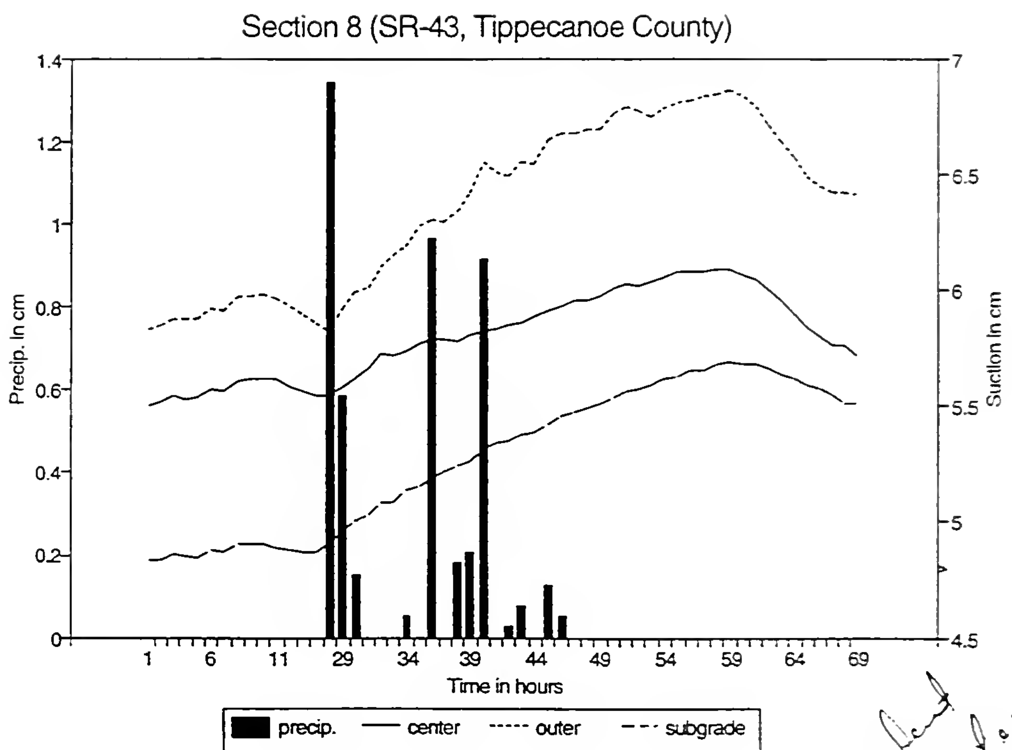


Figure 6.38 Suction variation in Section 6



moisture content greater in outer wheel path

Figure 6.39 Suction variation in Section 8

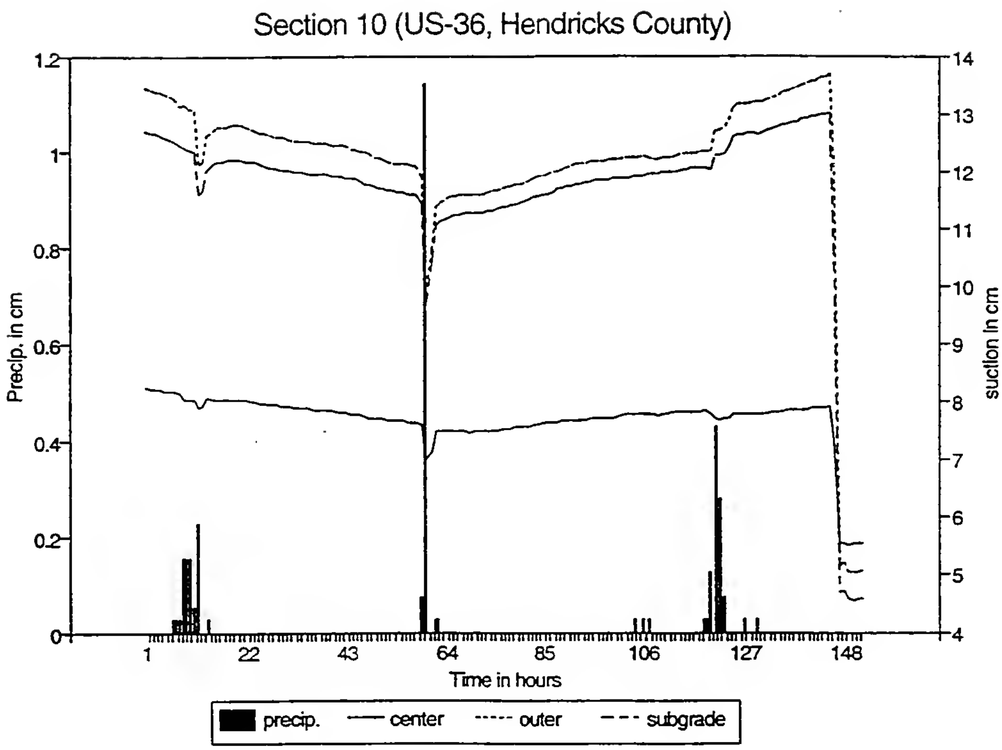


Figure 6.40 Suction variation in Section 10

investigations were carried out at each site. A more complete picture of the moisture variation can be obtained if studies are conducted over an annual cycle to account for the effects of freeze thaw.

CHAPTER 7 - CONCLUSIONS AND RECOMMENDATIONS

Research was conducted on the performance characteristics of existing pavement subsurface drainage systems through inspection of collector systems and using instrumentation techniques for monitoring the effects of moisture movement. Subgrade soils from the instrumented sections were studied in the laboratory to provide a data base on material properties, with special emphasis on application to the computer program PURDRAIN.

Inspection Process Conclusions

Specific Findings

Inspection of both old and new edge drain installations have resulted in the following conclusions:

1. Edge drains are effective in removing infiltrated water if care is taken during construction regarding slope, backfill compaction and outlet treatment.
2. Mesh type screens are more effective than other designs in preventing rodents and small animals from getting into the outlet pipes.
3. Treatment of the area around outlet pipes contribute

significantly to the proper functioning of collector systems. Vegetation growth, sedimentation and erosion around the outlet area reduce effectiveness of the system.

4. Edge drains on flat grades or at minimum slopes were observed to have the most problem with clogging. The outlet pipes at these points were partially buried due to absence of a freeboard between the outlet and roadside surface drainage,
5. Smooth walled plastic outlet pipes perform better than corrugated steel pipes as corrosion and sedimentation are more pronounced in the latter.
6. Care is required in backfilling and compacting trenches to avoid sags and collapse of the underdrain pipes and buckling of geotextile drains.
7. The type of fin drain inspected in this study has a tendency to buckle, as evident by camera observations and field excavations.
8. Infiltration of fines from base and subgrade soils surrounding the trench have resulted in clogged pipes, especially on flat slopes.
9. Most of the damage to outlet pipe openings result from mowing equipment.
10. T-connections are an impediment to inspection of pipe edge drains.
11. Backfilling around prefabricated edge drains with

excavated material results in an impervious layer coating the outside of the filter fabric. This tends to restrict water from entering the edge drains.

Recommendations

The following recommendations should be considered in performance improvment of collector systems:

1. The inspection methodology developed is recommended for use by INDOT in scheduling maintenance on edge drains.
2. The video imagescope serves as a valuable tool and its use is recommended for periodic inspection of collector systems.
3. Provide rip-rap protection or concrete pads to prevent erosion around the outlet area and damage by mowing equipment.
4. The outlet pipe should extend to the drainage ditch with a minimum freeboard of six inches.
5. Employ proper backfilling and compacting procedures be during construction to prevent sags and collapse of edge drains.
6. Use of a clean-out port and assembly using high water pressure is recommended for preventing sedimentation build-up and for clearing clogged pipes. The hose can be attached to a push rod as used with the camera system and inserted into the pipe from the outlet end.
7. Use is recommended of an improved product for

prefabricated edge drains.

8. Connect outlet pipes to edge drains with a 60 degree Y-connection to facilitate inspection and cleaning.
9. Backfill prefabricated edge drain trench with filter material to prevent clogging of drains.
10. Preparation of appropriate guidelines and directions by INDOT to incorporate, where appropriate, the findings of this research into the construction, inspection, maintenance and long term performance evaluation of edge drains.

Field And Laboratory Investigation Conclusions

The analysis of field and laboratory data has resulted in the following conclusions:

1. Pavement instrumentation can be used effectively in monitoring response of subdrainage systems to moisture infiltration. The selection of appropriate instruments is a key factor in acquiring good data on pavement subdrainage performance.
2. Gypsum moisture blocks used in the study, deteriorate rapidly in constant wet conditions or if placed in materials having high salt content. Results of performance of this study indicate it is not appropriate for pavement moisture studies.
3. Comprehensive laboratory testing has resulted in the development of a database on the hydraulic properties of

base/subbase materials and subgrade soils. This will help in calibrating and validating the computer program PURDRAIN and also in the analysis of new or retrofitted subdrainage systems by state highway agencies.

4. Measured values of the soil-moisture characteristic function '$\psi(\theta)$' compare very well with those estimated by Brooks and Corey's and Van Genuchten's models for subbase materials and subgrade soils. High correlations between measured and estimated values were obtained for both models.

5. The constant head permeameter used in the study is suitable for measuring permeabilities of cohesionless subgrade soils and base course materials having large size aggregates.

6. Edge drain outflow increases immediately for a precipitation event for pavements with unsealed edge joints. This indicates the pavement-shoulder joint to be a major source of surface moisture infiltration. Sealing edge joints will reduce this form of moisture infiltration.

7. Drainage outflow volumes are not solely influenced by intensity of precipitation. Material behavior and environmental conditions also affect the flow from the pavement subdrainage system.

8. Pavement and edge drain types have significant effects on the response of drainage outflow to precipitation.

9. The nature of the base/subbase layer has a major effect on the drainage outflow volumes. For identical pavement geometry, sections with more permeable base layers exhibited higher outflow volumes.
10. Most of the head buildup in subbase layers is due to development of a perched water table. Higher head values were recorded under pavement centers as compared to wheel paths.
11. Prolonged head buildup underneath pavements can lead to pumping.
12. Suction variation at test sites was insignificant due to fully or partially saturated condition of pavement layers and shorter duration of measurement.
13. Datalogger requirements restricted the number and placement depth of sensors in this study. Replicate sensors placed at various depths in pavement layers would provide better information on moisture movement.

Recommendations for Further Study

During the course of the project, the following areas were identified for further research.

1. Evaluation of suitable filter materials for trench backfills to address the problem of edge drain clogging.
2. Further research on monitoring pavement response to moisture infiltration using promising methods like Time-domain reflectrometry (TDR).

3. Development of a laboratory device to measure horizontal permeability of base layers. The permeameter should incorporate provisions for applying surcharge loads to simulate field conditions.
4. Studies on controlled test sections incorporating open graded and filter layers to optimize pavement subdrainage performance.

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APPENDICES

APPENDICES

Appendix A
Sample CR-10 Datalogger Program

```
Program: PAVEMENT SUBDRAINAGE STUDY
         JOINT HIGHWAY RESEARCH PROJECT
         PURDUE UNIVERSITY
         Site: US-31, HAMILTON COUNTY IN CARMEL
         Written: 10/20/90

Flag Usage: 1 - ACTIVATE 15 MINUTE OUTPUT
            2 - ACTIVATE HOURLY OUTPUT

Input Channel Usage:
     1D - DRUCK PDCR 831 PR. TRANSDUCER
          S/N 340581, 2.5 PSIG
          HOLE # 1, 14.50" DEPTH
     2D - DRUCK PDCR 831 PR. TRANSDUCER
          S/N 340582, 2.5 PSIG
          HOLE # 3, 14.25" DEPTH
     3D - DRUCK PDCR 831 PR. TRANSDUCER
          S/N 340583, 2.5 PSIG
          HOLE # 5, 14.50" DEPTH
     4D - DRUCK PDCR 831 PR. TRNASDUCER
          S/N 340584, 2.5 PSIG
          HOLE # 6, 14.50" DEPTH
     9S - DELMHORST SOIL MOISTURE BLOCK
          HOLE # 2, 14.5" DEPTH
    10S - DELMHORST SOIL MOISTURE BLOCK
          HOLE # 4, 14.00" DEPTH
    11S - DELMHORST SOIL MOISTURE BLOCK
          HOLE # 7, 14.50" DEPTH
    12S - THERMISTOR SOIL TEMPERATURE PROBE
          HOLE # 3, 14.50" DEPTH
    NOTE: D = DIFFERENTIAL;    S = SINGLE ENDED INPUTS

Excitation Channel Usage:
    1 - DRUCK PRESSURE TRANSDUCERS, 2500 MILLIVOLTS
    2 - DELMHORST SOIL MOISTURE BLOCKS, 2500 MILLIVOL
    3 - THERMISTOR TEMPERATURE PROBE, 2000 MILLIVOLTS


Control Port Usage:

Pulse Input Channel Usage:
   1 - RAIN GAGE, 0.01" PER TIP
   2 - FLOW TIPPING BUCKET, 1.1 LITERS PER TIP

Output Array Definitions:
    FIVE MINUTE OUTPUT
       1 - ARRAY ID (0001)
       2 - STATION ID
       3 - DAY OF YEAR
       4 - TIME (hhmm)
       5 - RAIN (inches)
       6 - AVG. FLOW FOR 5 MINUTES (gallons/minute)

    FIFTEEN MINUTE OUTPUT
       1 - ARRAY ID (0002)
       2 - STATION ID
       3 - DAY OF YEAR
       4 - TIME (hhmm)
       5 - RAIN (inches)
```

```
          6 - AVG. FLOW FOR 15 MINUTES (gallons/min)
          7 - DRUCK #1  (FT)
          8 - DRUCK #2  (FT)
          9 - DRUCK #3  (FT)
         10 - DRUCK #4  (FT)
         11 - DELMHORST #1  (FT)
         12 - DELMHORST #2  (FT)
         13 - DELMHORST #3  (FT)
         14 - SOIL TEMPERATURE (DEGREES FARENHEIT)
      HOURLY OUTPUT
          1 - ARRAY ID (0003)
          2 - STATION ID
          3 - DAY OF YEAR
          4 - TIME (hhmm)
          5 - RAIN (inches)
          6 - AVERAGE FLOW FOR 1 HOUR (gallons/min)
          7 - DRUCK #1  (FT)
          8 - DRUCK #2  (FT)
          9 - DRUCK #3  (FT)
         10 - DRUCK #4  (FT)
         11 - DELMHORST #1  (FT)
         12 - DELMHORST #2  (FT)
         13 - DELMHORST #3  (FT)
         14 - SOIL TEMPERATURE (DEGREES FARENHEIT)
      DAILY OUTPUT (AT 2400 HOURS)
          1 - ARRAY ID (0004)
          2 - STATION ID
          3 - DAY OF YEAR
          4 - TIME (hhmm)
          5 - RAIN (inches)
          6 - AVERAGE FLOW FOR 24 HOURS (gallons/min)
          7 - DRUCK #1  (FT)
          8 - DRUCK #2  (FT)
          9 - DRUCK #3  (FT)
         10 - DRUCK #4  (FT)
         11 - DELMHORST #1  (FT)
         12 - DELMHORST #2  (FT)
         13 - DELMHORST #3  (FT)
         14 - SOIL TEMPERATURE (DEGREES FARENHEIT)
         15 - BATTERY (VOLTS DC)

*        1        Table 1 Programs
  01: 300         Sec. Execution Interval

01:   P30         Z=F
  01: 3129        F
  02: 00          Exponent of 10
  03: 1           Z Loc [:STAT'N ID]

02:   P78         Resolution
  01: 1           High Resolution
```

```
03:  P3           Pulse
  01: 1           Rep
  02: 1           Pulse Input Chan
  03: 2           Switch closure
  04: 2           Loc [:RAIN TIPS]
  05: 1           Mult
  06: 0.0000      Offset

04:  P37          Z=X*F
  01: 2           X Loc RAIN TIPS
  02: 0.01        F
  03: 3           Z Loc [:RAIN/5MIN]

05:  P33          Z=X+Y
  01: 3           X Loc RAIN/5MIN
  02: 4           Y Loc RAIN/15MN
  03: 4           Z Loc [:RAIN/15MN] Rain(inches)for 15 minute out

06:  P33          Z=X+Y
  01: 3           X Loc RAIN/5MIN
  02: 5           Y Loc RAIN/1HR
  03: 5           Z Loc [:RAIN/1HR ] Rain(inches) for hourly outp

07:  P33          Z=X+Y
  01: 3           X Loc RAIN/5MIN
  02: 6           Y Loc RAIN/DAY
  03: 6           Z Loc [:RAIN/DAY ] Rain(inches) for daily output

08:  P3           Pulse
  01: 1           Rep
  02: 2           Pulse Input Chan
  03: 2           Switch closure
  04: 7           Loc [:FLOW TIPS]
  05: 1           Mult
  06: 0           Offset

09:  P37          Z=X*F
  01: 7           X Loc FLOW TIPS
  02: .26839      F
  03: 8           Z Loc [:FLOW/5MIN] (converts tips to gallons)

10:  P33          Z=X+Y
  01: 8           X Loc FLOW/5MIN
  02: 9           Y Loc FLOW/15MN
  03: 9           Z Loc [:FLOW/15MN] Flow(gal) for 15 minute outp

11:  P33          Z=X+Y
  01: 8           X Loc FLOW/5MIN
  02: 10          Y Loc FLOW/1 HR
  03: 10          Z Loc [:FLOW/1 HR] flow(gal) for hourly output

12:  P33          Z=X+Y
  01: 8           X Loc FLOW/5MIN
  02: 11          Y Loc FLOW/DAY
  03: 11          Z Loc [:FLOW/DAY ] Flow (gal) for daily output
```

```
13:   P89         If X<=>F
  01: 2           X Loc RAIN TIPS
  02: 3           >=
  03: 1           F
  04: 30          Then Do

14:   P86         Do
  01: 1           Call Subroutine 1

15:   P94         Else

16:   P89         If X<=>F
  01: 7           X Loc FLOW TIPS
  02: 3           >=
  03: 1           F
  04: 30          Then Do

17:   P86         Do
  01: 1           Call Subroutine 1 5 minute output

18:   P95         End

19:   P95         End

20:   P91         If Flag/Port
  01: 11          Do if flag 1 is high
  02: 30          Then Do

21:   P92         If time is
  01: 0           minutes into a
  02: 15          minute interval
  03: 30          Then Do

22:   P32         Z=Z+1
  01: 12          Z Loc [:TIMER 15M] Keeps 15 min. output active 6 hrs

23:   P86         Do
  01: 2           Call Subroutine 2 DELMHORST AND DRUCK SENSING

24:   P86         Do
  01: 3           Call Subroutine 3           15 MINUTE OUTPUT

25:   P95         End

26:   P95         End

27:   P91         If Flag/Port
  01: 12          Do if flag 2 is high
  02: 30          Then Do

28:   P92         If time is
  01: 0           minutes into a
  02: 60          minute interval
  03: 30          Then Do

29:   P32         Z=Z+1
  01: 23          Z Loc [:TIMER 1HR] Keeps 1 hour output active 24 hrs
```

```
30:  P86        Do
  01: 2         Call Subroutine 2    DELMHORST AND DRUCK SENSING

31:  P86        Do
  01: 4         Call Subroutine 4      TEMPERATURE SENSING

32:  P86        Do
  01: 5         Call Subroutine 5         HOURLY OUTPUT

33:  P95        End

34:  P95        End

35:  P92        If time is
  01: 0         minutes into a
  02: 1440      minute interval
  03: 30        Then Do

36:  P10        Battery Voltage
  01: 27        Loc [:BATTERY  ]      Monitors battery voltage

37:  P86        Do
  01: 2         Call Subroutine 2

38:  P86        Do
  01: 4         Call Subroutine 4

39:  P86        Do
  01: 6         Call Subroutine 6     DAILY OUTPUT (at 2400 hrs)

40:  P95        End

41:  P96        Serial Output
  01: 71        SM192/SM716

42:  P          End Table 1


*      2        Table 2 Programs
  01: 0.0000    Sec. Execution Interval

01:  P          End Table 2


*      3        Table 3 Subroutines

01:  P85        Beginning of Subroutine      5 MINUTE OUTPUT
  01: 1         Subroutine Number

02:  P37        Z=X*F
  01: 8         X Loc FLOW/5MIN
  02: .2        F
  03: 13        Z Loc [:flow1 GPM]   Average 5 min. flow in gal/min

03:  P86        Do
  01: 10        Set high Flag 0 (output)
```

```
04:  P80         Set Active Storage Area
  01: 1          Final Storage Area 1
  02: 1          Array ID or location

05:  P70         Sample
  01: 1          Reps
  02: 1          Loc STAT'N ID

06:  P77         Real Time
  01: 220        Day,Hour-Minute

07:  P70         Sample
  01: 1          Reps
  02: 3          Loc RAIN/5MIN

08:  P70         Sample
  01: 1          Reps
  02: 13         Loc flow1 GPM

09:  P86         Do
  01: 11         Set high Flag 1

10:  P30         Z=F
  01: 0          F
  02: 0          Exponent of 10
  03: 12         Z Loc [:TIMER 15M]    Reset Timer while rain occurs

11:  P30         Z=F
  01: 0          F
  02: 0          Exponent of 10
  03: 23         Z Loc [:TIMER 1HR]    Reset Timer during flow periods

12:  P95         End

13:  P85         Beginning of Subroutine
  01: 2          Subroutine Number      DELMHORST AND DRUCK SENSING

14:  P6          Full Bridge
  01: 4          Reps
  02: 23         25 mV 60 Hz rejection Range
  03: 1          IN Chan
  04: 1          Excite all reps w/EXchan 1
  05: 2500       mV Excitation
  06: 14         Loc [:DRUCK #1 ]
  07: 1          Mult
  08: 0          Offset

15:  P53         Scaling Array (A*loc +B)
  01: 14         Start Loc [:DRUCK #1 ]
  02: 2.3586     A1     Druck 1 (340581) Multiplier
  03: -.0556     B1     Druck 1 Offset
  04: 2.3347     A2     Druck 2 (340582) Multiplier
  05: -.0978     B2     Druck 2 Offset
  06: 2.3328     A3     Druck 3 (340583) Multiplier
  07: -.433      B3     Druck 3 Offset
  08: 2.3395     A4     Druck 4 (340584) Multiplier
  09: -.1915     B4     Druck 4 Offset
```

```
16:  P53        Scaling Array (A*loc +B)
  01: 14        Start Loc [:DRUCK #1 ]
  02: 1         A1
  03: 0         B1      Druck 1 Datum Correction
  04: 1         A2
  05: 0         B2      Druck 2 Datum Correction
  06: 1         A3
  07: 0         B3      Druck 3 Datum Correction
  08: 1         A4
  09: 0         B4      Druck 4 Datum Correction

17:  P5         AC Half Bridge
  01: 3         Reps
  02: 15        2500 mV fast Range
  03: 9         IN Chan
  04: 2         Excite all reps w/EXchan 2
  05: 2500      mV Excitation
  06: 18        Loc [:DELM SM 1]
  07: 1         Mult
  08: 0         Offset

18:  P59        BR Transform Rf[X/(1-X)]
  01: 3         Reps
  02: 18        Loc [:DELM SM 1]
  03: 1         Multiplier (Rf)

19:  P55        Polynomial
  01: 3         Reps
  02: 18        X Loc DELM SM 1
  03: 18        F(X) Loc [:DELM SM 1]
  04: .06516    C0
  05: .95117    C1
  06: -.25159   C2
  07: -.03736   C3
  08: .03723    C4
  09: -.00394   C5

20:  P53        Scaling Array (A*loc +B)
  01: 18        Start Loc [:DELM SM 1]
  02: 33.456    A1      Bars to feet conversion factor
  03: 0         B1
  04: 33.456    A2      Bars to feet conversion factor
  05: 0         B2
  06: 33.456    A3      Bars to feet coversion factor
  07: 0         B3
  08: 1         A4
  09: 0         B4

21:  P95        End

22:  P85        Beginning of Subroutine
  01: 3         Subroutine Number              15 MINUTE OUTPUT
```

```
23:  P89        If X<=>F
  01: 12        X Loc TIMER 15M
  02: 4         <
  03: 25        F
  04: 30        Then Do

24:  P30        Z=F
  01: 15        F
  02: 0         Exponent of 10
  03: 21        Z Loc [:FACTOR 15]    For 15 minute flow calculations

25:  P38        Z=X/Y
  01: 9         X Loc FLOW/15MN
  02: 21        Y Loc FACTOR 15
  03: 22        Z Loc [:FLOW2 GPM]     Average 15 minute flow in GPM

26:  P86        Do
  01: 10        Set high Flag 0 (output)

27:  P80        Set Active Storage Area
  01: 1         Final Storage Area 1
  02: 2         Array ID or location    Sets ID for 15 min. output

28:  P70        Sample
  01: 1         Reps
  02: 1         Loc STAT'N ID

29:  P77        Real Time
  01: 220       Day,Hour-Minute

30:  P70        Sample
  01: 1         Reps
  02: 4         Loc RAIN/15MN

31:  P70        Sample
  01: 1         Reps
  02: 22        Loc FLOW2 GPM

32:  P70        Sample
  01: 7         Reps
  02: 14        Loc DRUCK #1

33:  P30        Z=F
  01: 0         F
  02: 0         Exponent of 10
  03: 4         Z Loc [:RAIN/15MN]

34:  P30        Z=F
  01: 0         F
  02: 0         Exponent of 10
  03: 9         Z Loc [:FLOW/15MN]

35:  P86        Do
  01: 12        Set high Flag 2

36:  P94        Else
```

```
37:  P86       Do
  01: 21       Set low Flag 1

38:  P95       End

39:  P95       End

40:  P85       Beginning of Subroutine
  01: 4        Subroutine Number                  TEMPERATURE SENSING

41:  P11       Temp 107 Probe
  01: 1        Rep
  02: 12       IN Chan
  03: 3        Excite all reps w/EXchan 3
  04: 24       Loc [:temp'ture]
  05: 1.8      Mult
  06: 32       Offset     CONVERTS DEGREE CELSIUS INTO FARENHEIT

42:  P95       End

43:  P85       Beginning of Subroutine
  01: 5        Subroutine Number                   HOURLY OUTPUT

44:  P89       If X<=>F
  01: 23       X Loc TIMER 1HR
  02: 4        <
  03: 25       F
  04: 30       Then Do

45:  P30       Z=F
  01: 60       F
  02: 0        Exponent of 10
  03: 25       Z Loc [:FACTOR 1H]      For hourly flow calculation

46:  P38       Z=X/Y
  01: 10       X Loc FLOW/1 HR
  02: 25       Y Loc FACTOR 1H
  03: 26       Z Loc [:FLOW3 GPM]     Average hourly flow in GPM

47:  P86       Do
  01: 10       Set high Flag 0 (output)

48:  P80       Set Active Storage Area
  01: 1        Final Storage Area 1
  02: 3        Array ID or location    Sets ID for hourly output

49:  P70       Sample
  01: 1        Reps
  02: 1        Loc STAT'N ID

50:  P77       Real Time
  01: 220      Day,Hour-Minute

51:  P70       Sample
  01: 1        Reps
  02: 5        Loc RAIN/1HR
```

```
52:   P70         Sample
  01: 1           Reps
  02: 26          Loc FLOW3 GPM

53:   P70         Sample
  01: 7           Reps
  02: 14          Loc DRUCK #1

54:   P70         Sample
  01: 1           Reps
  02: 24          Loc temp'ture

55:   P30         Z=F
  01: 0           F
  02: 0           Exponent of 10
  03: 5           Z Loc [:RAIN/1HR ]

56:   P30         Z=F
  01: 0           F
  02: 0           Exponent of 10
  03: 10          Z Loc [:FLOW/1 HR]

57:   P94         Else

58:   P86         Do
  01: 22          Set low Flag 2

59:   P30         Z=F
  01: 0           F
  02: 0           Exponent of 10
  03: 23          Z Loc [:TIMER 1HR]

60:   P95         End

61:   P95         End

62:   P85         Beginning of Subroutine
  01: 6           Subroutine Number             DAILY OUTPUT

63:   P30         Z=F
  01: 1440        F
  02: 0           Exponent of 10
  03: 28          Z Loc [:FACTOR dy]      For daily flow calculations

64:   P38         Z=X/Y
  01: 11          X Loc FLOW/DAY
  02: 28          Y Loc FACTOR dy
  03: 29          Z Loc [:FLOW4 GPM]     Average daily flow in GPM

65:   P86         Do
  01: 10          Set high Flag 0 (output)

66:   P80         Set Active Storage Area
  01: 1           Final Storage Area 1
  02: 4           Array ID or location    Sets ID for daily output
```

```
67:  P70        Sample
  01: 1         Reps
  02: 1         Loc STAT'N ID

68:  P77        Real Time
  01: 321       Day,Hour-Minute

69:  P70        Sample
  01: 1         Reps
  02: 6         Loc RAIN/DAY

70:  P70        Sample
  01: 1         Reps
  02: 29        Loc FLOW4 GPM

71:  P70        Sample
  01: 7         Reps
  02: 14        Loc DRUCK #1

72:  P70        Sample
  01: 1         Reps
  02: 24        Loc temp'ture

73:  P70        Sample
  01: 1         Reps
  02: 27        Loc BATTERY

74:  P30        Z=F
  01: 0         F
  02: 0         Exponent of 10
  03: 6         Z Loc [:RAIN/DAY ]          Reset rain counter

75:  P30        Z=F
  01: 0         F
  02: 0         Exponent of 10
  03: 11        Z Loc [:FLOW/DAY ]          Reset flow counter

76:  P95        End

77:  P          End Table 3


*      A        Mode 10 Memory Allocation
  01: 29        Input Locations
  02: 64        Intermediate Locations
  03: 0.0000    Final Storage Area 2


*      C        Mode 12 Security
  01: 0         LOCK 1
  02: 0         LOCK 2
  03: 0000      LOCK 3
```

Key:
T=Table Number
E=Entry Number
L=Location Number

T:	E:	L:		
1:	1:	1:	Z Loc [:STAT'N ID]	
1:	3:	2:	Loc [:RAIN TIPS]	
1:	4:	3:	Z Loc [:RAIN/5MIN]	
1:	5:	4:	Z Loc [:RAIN/15MN]	Rain(inches)for 15 minute output
3:	33:	4:	Z Loc [:RAIN/15MN]	
1:	6:	5:	Z Loc [:RAIN/1HR]	Rain(inches) for hourly output
3:	55:	5:	Z Loc [:RAIN/1HR]	
1:	7:	6:	Z Loc [:RAIN/DAY]	Rain(inches) for daily output
3:	74:	6:	Z Loc [:RAIN/DAY]	Reset rain counter
1:	8:	7:	Loc [:FLOW TIPS]	
1:	9:	8:	Z Loc [:FLOW/5MIN]	(converts tips to gallons)
1:	10:	9:	Z Loc [:FLOW/15MN]	Flow(gal) for 15 minute output
3:	34:	9:	Z Loc [:FLOW/15MN]	
1:	11:	10:	Z Loc [:FLOW/1 HR]	flow(gal) for hourly output
3:	56:	10:	Z Loc [:FLOW/1 HR]	
1:	12:	11:	Z Loc [:FLOW/DAY]	Flow (gal) for daily output
3:	75:	11:	Z Loc [:FLOW/DAY]	Reset flow counter
1:	22:	12:	Z Loc [:TIMER 15M]	Keeps 15 min. output active 6 hrs
3:	10:	12:	Z Loc [:TIMER 15M]	Reset Timer while rain occurs
3:	2:	13:	Z Loc [:flow1 GPM]	Average 5 min. flow in gal/min
3:	14:	14:	Loc [:DRUCK #1]	
3:	15:	14:	Start Loc [:DRUCK #1]	
3:	16:	14:	Start Loc [:DRUCK #1]	
3:	17:	18:	Loc [:DELM SM 1]	
3:	18:	18:	Loc [:DELM SM 1]	
3:	19:	18:	F(X) Loc [:DELM SM 1]	
3:	20:	18:	Start Loc [:DELM SM 1]	
3:	24:	21:	Z Loc [:FACTOR 15]	For 15 minute flow calculations
3:	25:	22:	Z Loc [:FLOW2 GPM]	Average 15 minute flow in GPM
1:	29:	23:	Z Loc [:TIMER 1HR]	Keeps 1 hour output active 24 hrs
3:	11:	23:	Z Loc [:TIMER 1HR]	Reset Timer during flow periods
3:	59:	23:	Z Loc [:TIMER 1HR]	
3:	41:	24:	Loc [:temp'ture]	
3:	45:	25:	Z Loc [:FACTOR 1H]	For hourly flow calculations
3:	46:	26:	Z Loc [:FLOW3 GPM]	Average hourly flow in GPM
1:	36:	27:	Loc [:BATTERY]	Monitors battery voltage
3:	63:	28:	Z Loc [:FACTOR dy]	For daily flow calculations
3:	64:	29:	Z Loc [:FLOW4 GPM]	Average daily flow in GPM

Appendix B
List and Cost of Instrumentation

DATALOGGER SYSTEM

Item	Description	Qty.	Unit Price	Total Cost
1	Campbell Scientific CR10 Measurement and Control Module w/WP Wiring Panel	1		1010.00
2	CR-10 Keyboard and Display	1		250.00
3	Solid State Storage Module (96,000 data values) for CR-10, SM#192	1		450.00
4	Peripheral Connector Cable for Datalogger, #SC12	2	20.00	40.00
5	C-Cell Battery Pack for CR-10, #10ALK/C (12volts)	1		60.00
6	Clock-S.O Tape Read Card and software for IBM-PC #PC20	1		500.00
7	PC-201 Storage Module Connector Cable, #SC 209	1		25.00
8	Datalogger Support Software #PC 208	1		200.00

MEASUREMENT SYSTEMS

Item	Description	Qty.	Unit Price	Total Cost
1	Delmhorst Gypsum Moisture Blocks, #GB-1	5	7.00	35.00
2	Tantalum 100 microfarad capacitors for gypsum blocks	20	2.50	60.00
3	1 kohm resistors for gypsum	5	0.60	3.00
4	Druck Depth/Level Pressure Transducer PDCR831 w/300 feet additional lead cables	4	656.00	2624.00
5	Campbell Scientific Thermistor Temperature Probe w/additional lead cable, #107B	1		57.00

Item	Description	Qty	Unit Price	Total Cost
6	Texas Instrument Raingage #TE525	1		246.00
7	Outflow Tipping Bucket, Purdue University Central Machine Shop	1		400.00
	MISCELLANEOUS			
1	Wooden Enclosure House, Purdue University Physical Plant, Carpentry Section	1		400.00
2	PVC Junction Box with removable lid	1		32.00
3	PVC Flexible Coupling 4"x6"	1		20.00
4	PVC Pipe 2" diameter	50'	0.50	25.00
5	PVC Fittings 2" dia.	12	0.50	6.00

Appendix C
Condition Survey Data Sheets

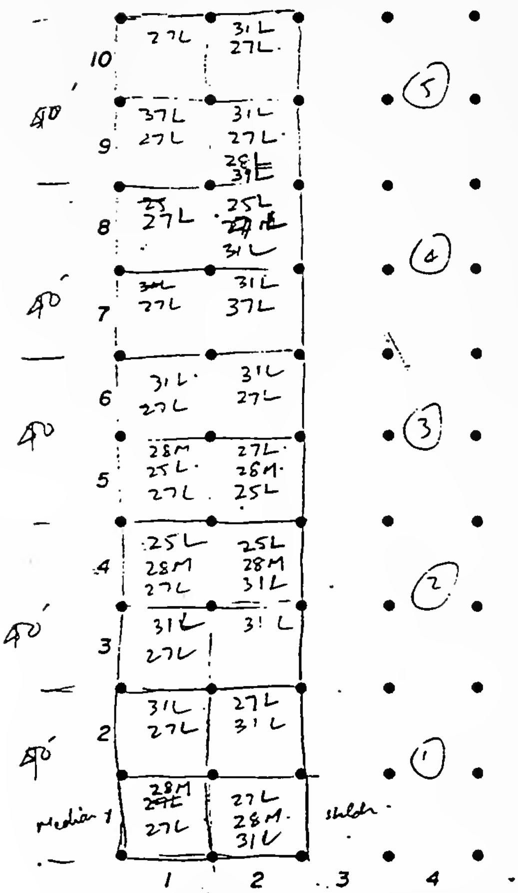
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH [illegible] SECTION [illegible]

DATE 10/7/90 SAMPLE UNIT 1

SURVEYED BY [illegible] SLAB SIZE 24' x 40'



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Smal.
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, U Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	L			
25	L	5	25	
27	L	17	85	
28	L	1	5	
28	M	6	30	
31	L	11	55	
37	L	2	10	
39	L	1	5	
q=	TOTAL DEDUCT VALUE			
CORRECTED DEDUCT VALUE (CDV)				

PCI = 100 − CDV = ______

RATING = ______

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

Avg. PCI = 71.076
Avg. Rating = V. Good

DA FORM 5145-R, NOV 82

* Reinf. Conc. NB

Figure E-1.

397-510 O - 83 - 11 : QL 3

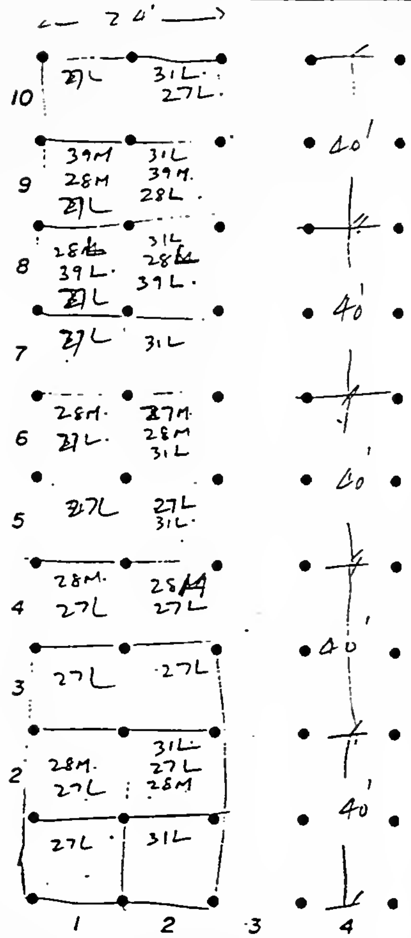
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-31 SECTION #13 JRCP

DATE [illegible] SAMPLE UNIT 2

SURVEYED BY Z. AHMED SLAB SIZE 24'x40'



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Smal.
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, U Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	L			
27	L	15	75	
27	M	1	5	
28	L	2	10	
28	M	7	35	
31	L	8	40	
39	L	2	10	
39	M	2	10	
q=	TOTAL DEDUCT VALUE			
CORRECTED DEDUCT VALUE (CDV)				

PCI = 100 - CDV = ______

RATING = ______

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Figure E-1.

397-550 0 - 83 - 31 : QL 3

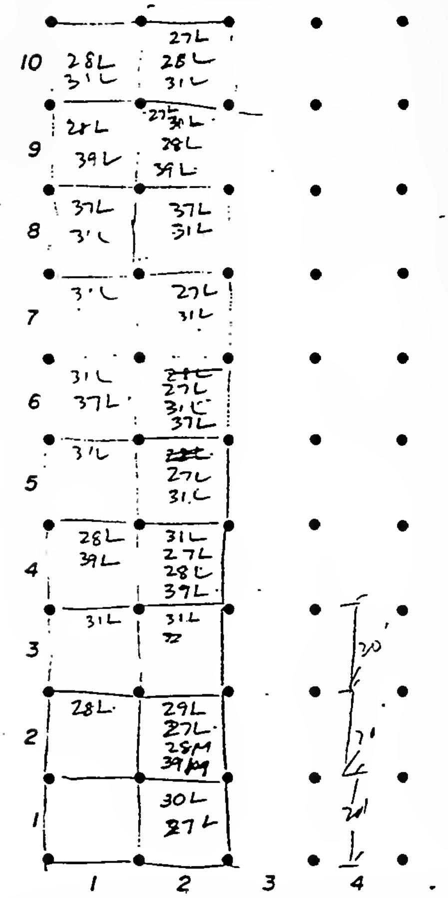
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH 95-31 SECTION EB JRCP

DATE 10/7/81 SAMPLE UNIT 3

SURVEYED BY Z. AHMED SLAB SIZE 24' × 20'



Distress Types

21. Blow-Up Buckling/Shattering	31. Polished Aggregate
22. Corner Break	32. Popouts
23. Divided Slab	33. Pumping
24. Durability ("D") Cracking	34. Punchout
25. Faulting	35. Railroad Crossing
26. Joint Seal Damage	36. Scaling/Map Cracking/Crazing
27. Lane/Shldr Drop Off	37. Shrinkage Cracks
28. Linear Cracking	38. Spalling, Corner
29. Patching, Large & Util Cuts	39. Spalling, U Joint
30. Patching, Small	

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	L			
27	L	8	40	
28	L	7	35	
28	M	1	5	
30	L	1	5	
31	L	14	70	
37	L	4	20	
39	L	4	20	
39	M	1	5	
q=	TOTAL DEDUCT VALUE			
CORRECTED DEDUCT VALUE (CDV)				

PCI = 100 − CDV = ______

RATING = ______

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Figure E-1.

392-550 0 - 83 - 33 : QL 3

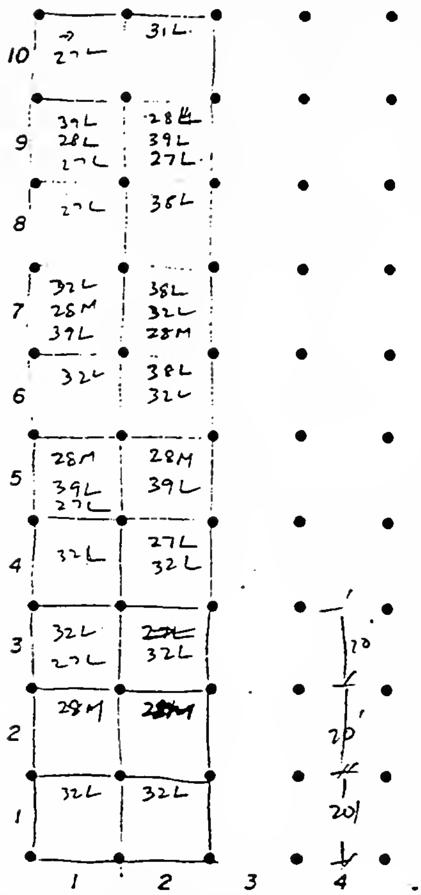
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH [illegible] SECTION F/B [illegible]

DATE [illegible] SAMPLE UNIT [illegible]

SURVEYED BY [illegible] SLAB SIZE 2_' x 20'



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Smal.
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	L			
27	L	7	35	
28	L	2	10	
28	M	6	30	
31	L	1	5	
32	L	10	50	
38	L	3	15	
39	L	5	25	

q= TOTAL DEDUCT VALUE

CORRECTED DEDUCT VALUE (CDV)

PCI = 100 − CDV =

RATING =

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Figure E-1.

* Alligator cracks on the sealed shoulder next to embankment slope.

397-550 0 - 83 - 21 : QL 3

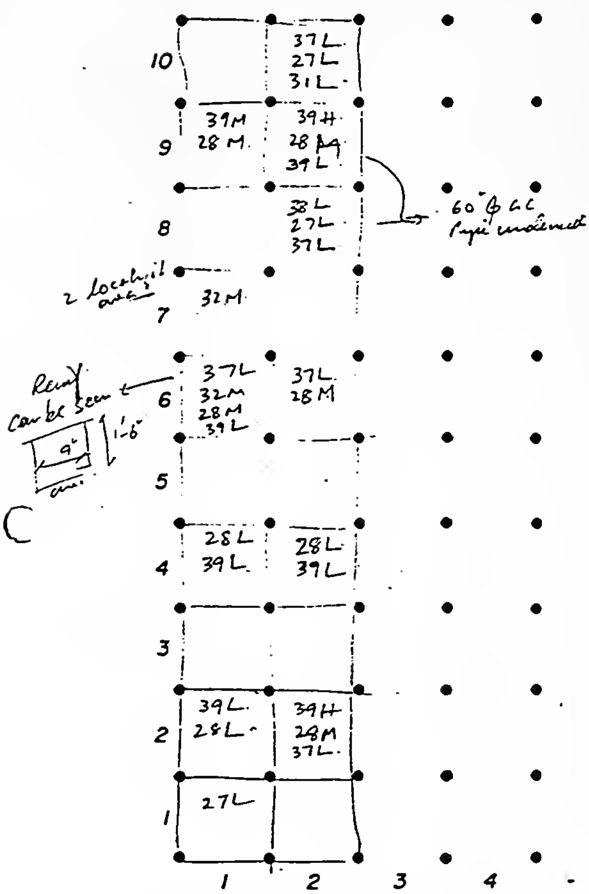
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH: US 31 [illegible] SECTION: NB JRCP

DATE: 10/7/90 SAMPLE UNIT: 5

SURVEYED BY: Z. AHMED SLAB SIZE: 24' x 40'



Distress Types

- 21. Blow-Up Buckling/Shattering
- 22. Corner Break
- 23. Divided Slab
- 24. Durability ("D") Cracking
- 25. Faulting
- 26. Joint Seal Damage
- 27. Lane/Shldr Drop Off
- 28. Linear Cracking
- 29. Patching, Large & Util Cuts
- 30. Patching, Small
- 31. Polished Aggregate
- 32. Popouts
- 33. Pumping
- 34. Punchout
- 35. Railroad Crossing
- 36. Scaling/Map Cracking/Crazing
- 37. Shrinkage Cracks
- 38. Spalling, Corner
- 39. Spalling, Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	L			
27	L	3	15	
28	L	3	15	
28	M	5	25	
31	L	1	5	
32	M	2	10	
37	L	5	25	
39	L	4	20	
37	M	1	5	
39	H	2	10	
q=	TOTAL DEDUCT VALUE			
CORRECTED DEDUCT VALUE (CDV)				

PCI = 100 − CDV = 67.72

RATING = Good

The pvt. opposite the 2nd drain outlet is marked.

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Figure E-1.

* In front of the outlet pipe when the instrumentation is going to be done.

ASPHALT PAVEMENT INSPECTION SHEET

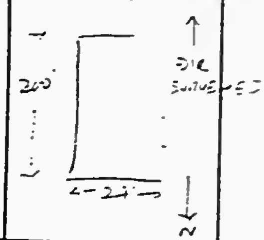
For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR - 37 / HAMILTON SECTION '2' S.B
DATE 7/17/90 SAMPLE UNIT 1
SURVEYED BY Z. A. AREA OF SAMPLE [illegible]

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

	TYPE →	10	7	15			
QUANTITY & SEVERITY		24'x3 L	5 L	200x3' L			
		24'x4 M					
		200' L					
		5' L					
TOTAL SEVERITY	L	253	5	600			
	M	96					
	H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	0.104	L	0
10	5.27	L	11
10	2	M	14
15	12.5	L	30
q= 3	TOTAL DEDUCT VALUE		55
CORRECTED DEDUCT VALUE (CDV)			35

PCI = 100 - CDV = 65

RATING = GOOD.

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

* Shoulder length = 7' → Chip Sealed Bit. Shoulder.
* TRANSVERSE CRACKS IN SHOULDER.
* Med. Shoulder on median side = [illegible]

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-37 SECTION 2'-5 B

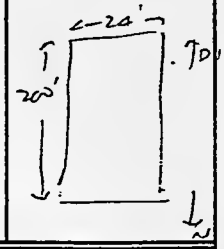
DATE 7/17/90 SAMPLE UNIT 2

SURVEYED BY 2. A AREA OF SAMPLE 4800 sf

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
4. * Bumps and Sags
5. Corrugation
6. Depression
7. * Edge Cracking
8. * Jt Reflection Cracking
9. * Lane/Shldr Drop Off
10. * Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. * Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



Dir. of survey

EXISTING DISTRESS TYPE. QUANTITY & SEVERITY

TYPE →	7	15	10	19	1	17
QUANTITY & SEVERITY	30 M	20'x 3' L	24'x 2 L	200' x 3' L	12'x 4' L	2'x 2' L
	12 M		24'x 1 M	10'x 2' L		
	100' L		20'x 3 L			
			150' L			
						Negl.
TOTAL SEVERITY L	100	600	318	700	48	4
TOTAL SEVERITY M	52		24			
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
1	1	L	11
7	2.08	L	4
7	1.08	M	8
10	6.63	L	11
10	0.5	M	4
15	12.5	L	29
19	14.6	L	6
q=5	TOTAL DEDUCT VALUE		73
CORRECTED DEDUCT VALUE (CDV)			37

PCI = 100 − CDV = 63

RATING = GOOD

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

* Grass not mowed alongside the shoulder. and median
* Transverse Cracks at every 15→20' on the Lt shoulder propagating towards pvt.
* There is a definite line of long. cracking at 14' from the median edge of the pvt.

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-37 SECTION (2) S B

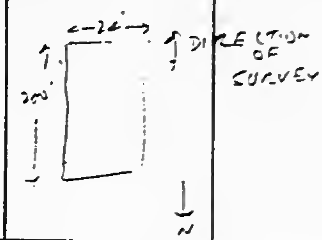
DATE 7/17/90 SAMPLE UNIT 3

SURVEYED BY Z. A. AREA OF SAMPLE 45[illegible]

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	10	19	15	13	1	
QUANTITY & SEVERITY	24'×1 L	200'×4' L	200'×2' L	1 L	30×2' L	
	14'×7 L					
	200' L					
TOTAL SEVERITY L	322	800	400	1	60	
M						
H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
1	1.25	L	12
10	6.7	L	13
13	0.02	L	6
15	8.33	L	26
19	16.67	L	7
q=5	TOTAL DEDUCT VALUE		64
CORRECTED DEDUCT VALUE (CDV)			33

PCI = 100 − CDV = 67

RATING = GOOD

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

* Sh. Transv Cracks every 15 to 20'
* Rutting is at 14' from the median side, where also the longitudinal cracks are located.

ASPHALT PAVEMENT INSPECTION SHEET

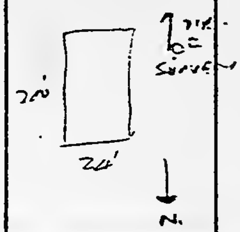
For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-37	SECTION '2' SB
DATE 7/17/90	SAMPLE UNIT 4
SURVEYED BY 2-A	AREA OF SAMPLE 48 [illegible]

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →		10	1	7		
QUANTITY & SEVERITY		24×2 L	3'×[illegible]	70' L		
		50' L	½'×1' L			
		72'×2 L				
		15' L				
		2×10' L				
		1×5' L				
		30' L				
TOTAL SEVERITY L		202	22	70		
TOTAL SEVERITY M						
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
1	0.46	L	6
7	1.46	L	3
10	4.2	L	9
q= 2	TOTAL DEDUCT VALUE		18
CORRECTED DEDUCT VALUE (CDV)			13

PCI = 100 − CDV = 87

RATING = V. GOOD

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

x Shldr. Trans. Cracks propagate into pvt.

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH 50-37 SECTION (2) S.B.

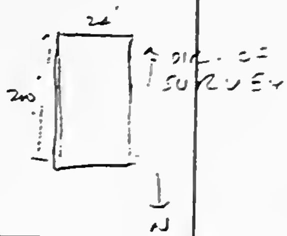
DATE 7/17/90 SAMPLE UNIT 5

SURVEYED BY Z.A AREA OF SAMPLE [illegible]

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	1	10	17	19	15	
QUANTITY & SEVERITY	7'×3' L	12' L	6'×1' L	120'×4' L	10'×1' L	
		12' L				
		20' L				
		10' L				
		100' L				
TOTAL SEVERITY L	21	154	6	480	10	
M						
H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
1	0.44	L	6
10	3.21	L	7
15	0.21	L	2
17	0.125	L	0
19	10	L	5
q= 2	TOTAL DEDUCT VALUE		20
CORRECTED DEDUCT VALUE (CDV)			15

PCI = 100 − CDV = 85

RATING = V. GOOD

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

* Ref. Cracking from Shoulder propagating 4' into pvt

ASPHALT PAVEMENT INSPECTION SHEET

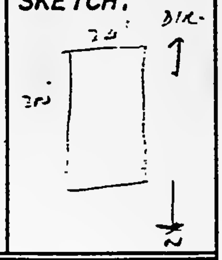
For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-37/HAMILTON SECTION (2) SB
DATE 7/17/90 SAMPLE UNIT 6
SURVEYED BY Z. A. AREA OF SAMPLE 250 sf

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE. QUANTITY & SEVERITY

TYPE →	1	10	7			
QUANTITY & SEVERITY	6'x3' L	3' M	80' L			
	10'x2' L	12' L	30' L			
	25'x1' L	10' L				
	20'x1' L	22' L				
	2'x2' L	4'x5 L				
		2x12' L				
		24'x7 L				
TOTAL SEVERITY L	123	138	110			
M		3				
H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
1	2.56	L	18
7	2.29	L	4
10	2.88	L	6
10	0.06	M	0
q= 2	TOTAL DEDUCT VALUE		28
CORRECTED DEDUCT VALUE (CDV)			21

PCI = 100 - CDV = 79

RATING = V. GOOD

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

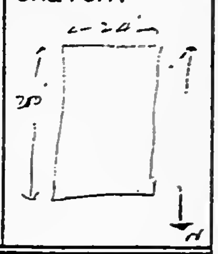
* Shoulder Transverse Cracks propagate 4' into pvt

(15)

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-37　　SECTION '2' SB
DATE 7/17/96　　SAMPLE UNIT 7
SURVEYED BY T. A.　　AREA OF SAMPLE 4800 :?

Distress Types		SKETCH:
1. Alligator Cracking	*10. Long & Trans Cracking	
2. Bleeding	11. Patching & Util Cut Patching	
3. Block Cracking	12. Polished Aggregate	
*4. Bumps and Sags	*13. Potholes	
5. Corrugation	14. Railroad Crossing	
6. Depression	15. Rutting	
*7. Edge Cracking	16. Shoving	
*8. Jt Reflection Cracking	17. Slippage Cracking	
*9. Lane/Shldr Drop Off	18. Swell	
	19. Weathering and Raveling	

Dir. of Survey

EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE	10	17	1	19		
QUANTITY & SEVERITY	24' M	2'x1' L	10'x1' L	20'x2' L		
	5' L		12'x1' L			
			35'x1' L			
TOTAL SEVERITY L	5	2	62	40		
TOTAL SEVERITY M	24					
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
1	1.29	L	12
10	0.1	L	0
10	0.5	M	4
17	0.04	L	0
19	0.83	L	2
q= 1	TOTAL DEDUCT VALUE		18
CORRECTED DEDUCT VALUE (CDV)			18

PCI = 100 - CDV = 82

RATING = V. GOOD

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

* Shoulder Trans. Cracks are propagating into the pvt.

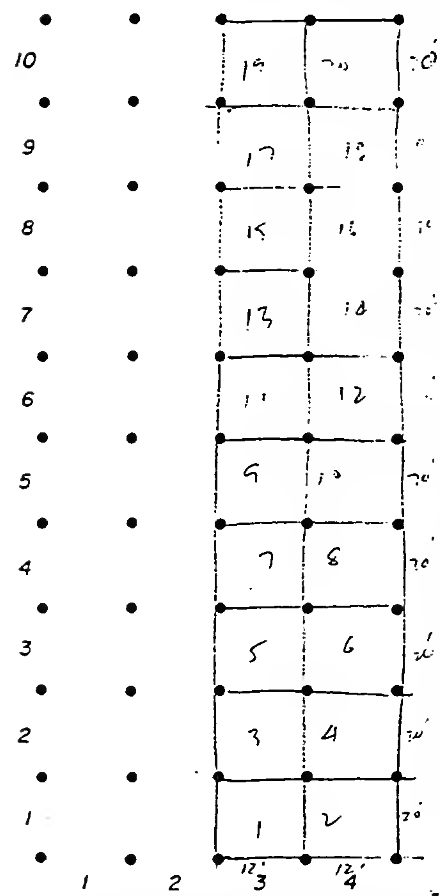
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623: the proponent agency is USACE.

BRANCH SR-37, BEDFORD SECTION SB

DATE 9/25/91 SAMPLE UNIT 1

SURVEYED BY Z. AHMED SLAB SIZE 12' x 20'



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Smal.
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*				
31	-	20	100	
q=	TOTAL DEDUCT VALUE			
CORRECTED DEDUCT VALUE (CDV)				

PCI = 100 - CDV = ______

RATING = ______

Avg. PCI = 85.97 = Excellent

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Figure E-1.

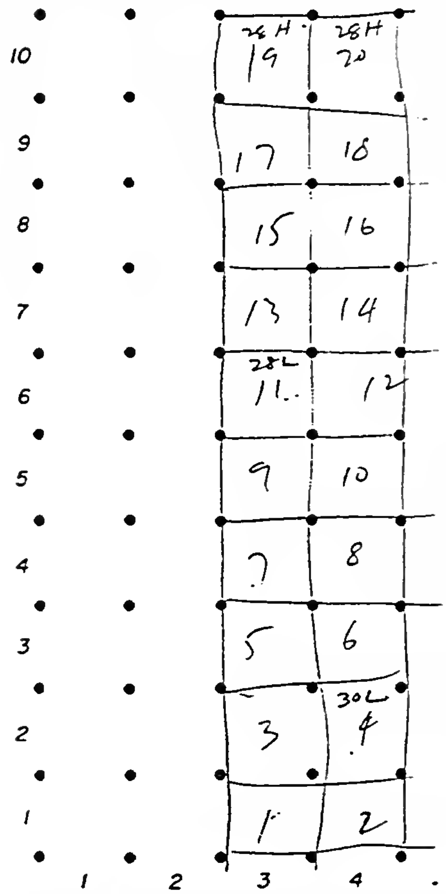
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-37 Bedford SECTION SB

DATE 9/25/91 SAMPLE UNIT 2

SURVEYED BY Z. AHMED; H. COSME SLAB SIZE 12 x 20



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Smal.
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, U Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*				
31	L	20	10	
30	L	1	5	
28	L	1	5	
28	H	2	10	
q=	TOTAL DEDUCT VALUE			
CORRECTED DEDUCT VALUE (CDV)				

PCI = 100 − CDV = ______

RATING = ______

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Section above US [illegible]

Figure E-1.

392-550 0 - 83 - 31 : QL 3

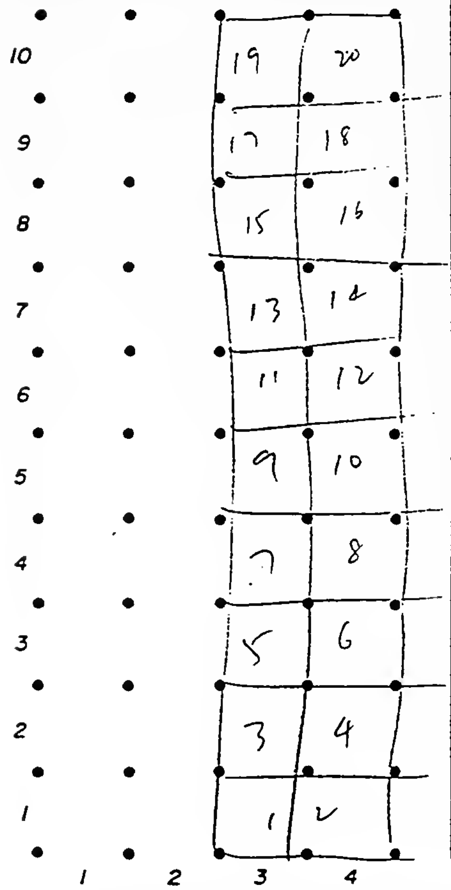
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-37, BEDFORD SECTION SB

DATE 9/25/91 SAMPLE UNIT 3

SURVEYED BY [illegible] SLAB SIZE 12 x 36



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Small
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*				
31	L	20	100	
q=	TOTAL DEDUCT VALUE			
CORRECTED DEDUCT VALUE (CDV)				

PCI = 100 − CDV = ______

RATING = ______

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Figure E-1.

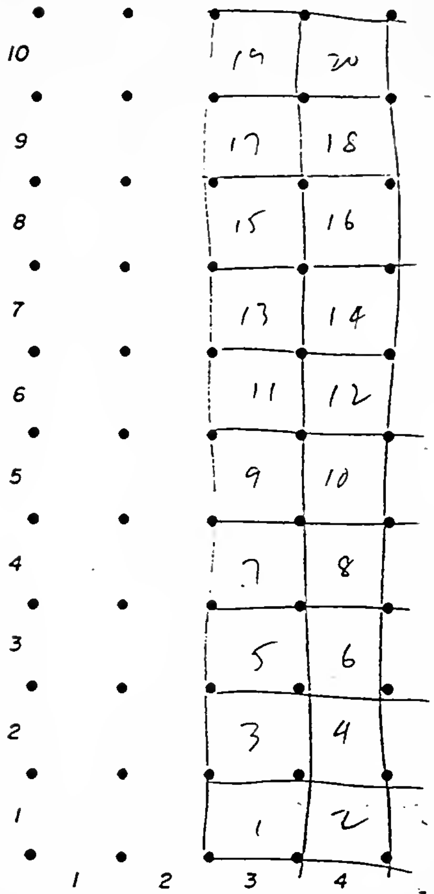
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-37 Bedford. SECTION SB

DATE 9/25/91. SAMPLE UNIT 4

SURVEYED BY J. AHMED; H. COSMO SLAB SIZE 12' x 30'



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Smal.
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, U Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*				
31	L	22	10	
38	M	1	5	
~~33~~ 38	L	1	5	
27	L	4.	20	
q=	TOTAL DEDUCT VALUE			
CORRECTED DEDUCT VALUE (CDV)				

PCI = 100 - CDV = ______

RATING = ______

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Figure E-1.

397-510 0 - 83 - 11 : QL 3

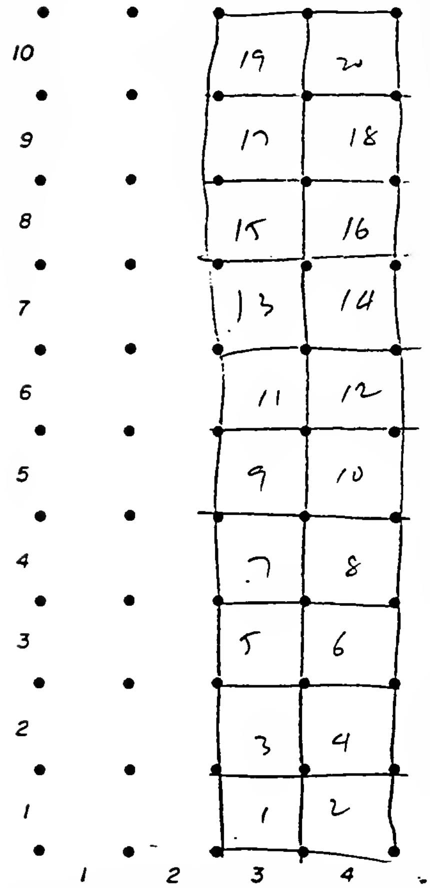
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-37, BEDFORD SECTION 5B

DATE 9/25/91 SAMPLE UNIT 5

SURVEYED BY Z. AHMED; L. COSINO SLAB SIZE 12' x 20'



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Smal.
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, U Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*				
31	L	20	100	
38	L	1	5	
27	L	1	5	
q= ,	TOTAL DEDUCT VALUE			
CORRECTED DEDUCT VALUE (CDV)				

PCI = 100 - CDV = ________

RATING = ________

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Figure E-1.

392-550 0 - 83 - 21 : QL 3

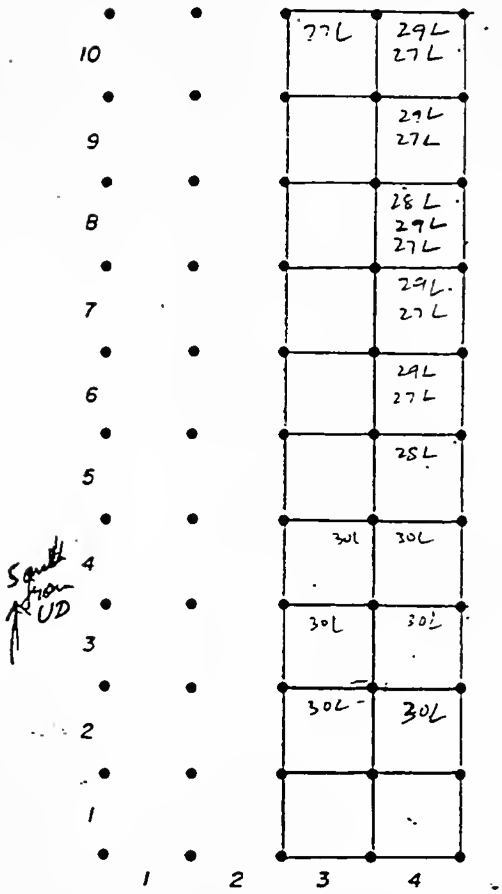
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-41, SULLIVAN SECTION SB

DATE 5/15/92 SAMPLE UNIT 1

SURVEYED BY Z. AHMED SLAB SIZE 12' × 20'



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Smal.
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	L			2
27	L	5	25	2
28	L	2	10	6
29	L	5	25	9
30	L	6	30	2
q= 2	TOTAL DEDUCT VALUE			21
CORRECTED DEDUCT VALUE (CDV)				16

PCI = 100 − CDV = 84

RATING = V. Good

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress26, Which Is Rated For the Entire Sample Unit.

* Shldr is in bad condition; Coarse Agg. has started to peel off

DA FORM 5145-R, NOV 82

Overall PCI = 79.17
Rating = GOOD

Figure E-1.

292-550 0 - 83 - 31 : QL 3

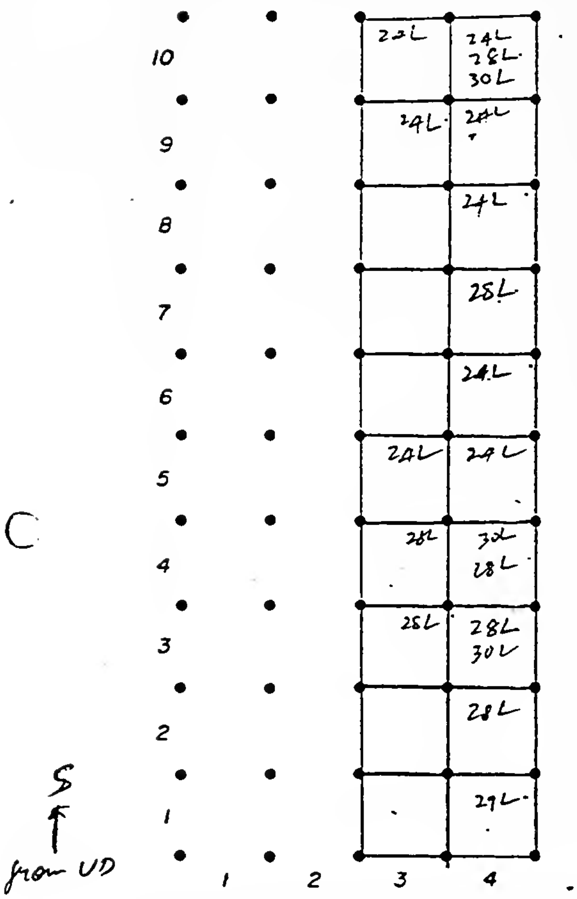
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-41, SULLIVAN SECTION SB

DATE 5/5/92 SAMPLE UNIT 2

SURVEYED BY Z. AHMED SLAB SIZE 12 x 20



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Small
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	L			2
24	L	8	40	13
28	L	7	35	14
29	L	1	5	0
30	L	3	15	0
q= 2	TOTAL DEDUCT VALUE			29
CORRECTED DEDUCT VALUE (CDV)				23

PCI = 100 - CDV = 77

RATING = V. Good

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Figure E-1.

397-510 O - 83 - 11 : QL 3

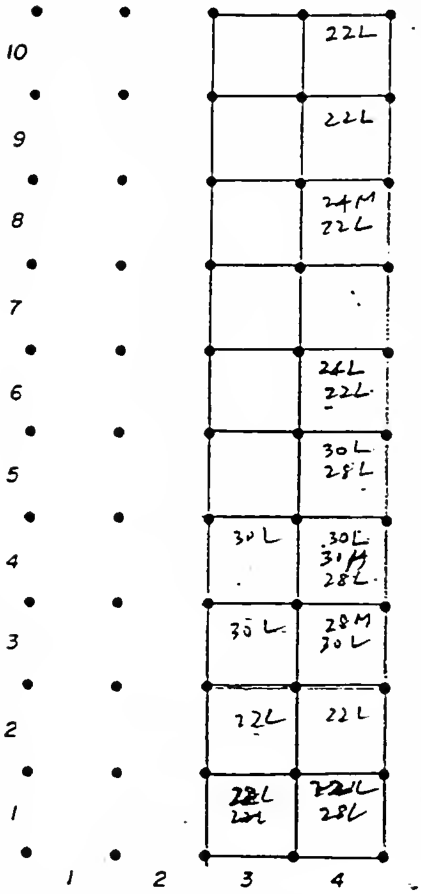
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-41 SULLIVAN SECTION SB

DATE 5/15/92 SAMPLE UNIT 3

SURVEYED BY Z-AHMED SLAB SIZE 12' x 20'



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Smal.
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, U Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	L			2
22	L	8	40	32
24	L	1	5	2
24	M	1	5	5
28	L	3	15	8
28	M	1	5	5
30	L	4	20	1
30	H	1	5	2
q= 4	TOTAL DEDUCT VALUE			57
CORRECTED DEDUCT VALUE (CDV)				33

PCI = 100 − CDV = 67

RATING = GOOD

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Figure E-1.

392-550 0 - 83 - 11 . QL 3

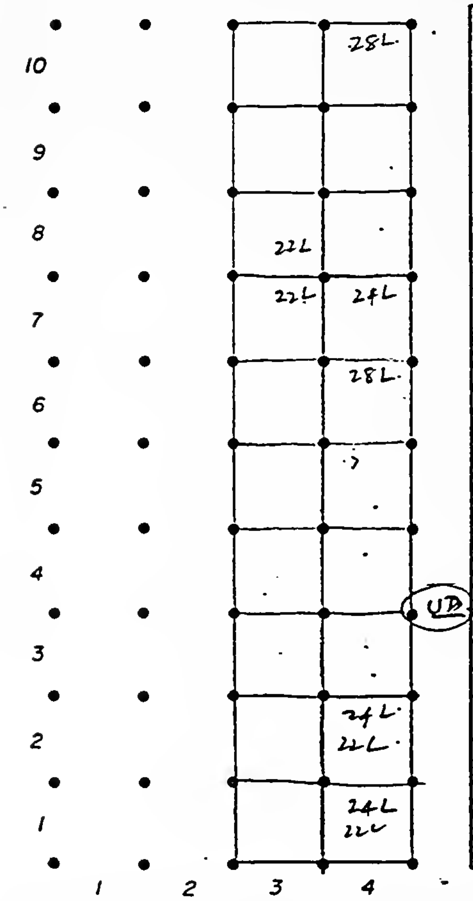
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-41, SULLIVAN SECTION SB

DATE 5/15/92 SAMPLE UNIT 4

SURVEYED BY Z. AHMED SLAB SIZE 12' x 20'



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Small
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	L			2
22	L	4	20	17
24	L	3	15	6
28	L	2	10	6
q= 3	TOTAL DEDUCT VALUE			31
CORRECTED DEDUCT VALUE (CDV)				19

PCI = 100 - CDV = 81

RATING = V-Good.

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Figure E-1.

392-550 0 - 83 - 11 : QL 3

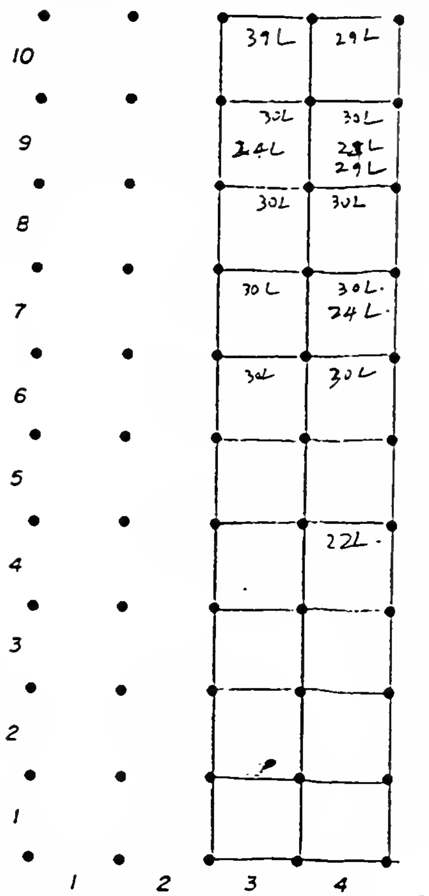
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-41, SULLIVAN　　SECTION SB

DATE 5/15/92　　SAMPLE UNIT 5

SURVEYED BY Z. AHMED　　SLAB SIZE 12' x 20'



N from U.D.

Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Smal.
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	L			2
22	L	1	5	4
24	L	3	15	6
29	L	1	5	0
30	L	8	40	2
39	L	1	5	1

q= 1　TOTAL DEDUCT VALUE 15

CORRECTED DEDUCT VALUE (CDV) 15

PCI = 100 − CDV = 85

RATING = V. Good

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Figure E-1.

392-550 0 - 83 - 11 : QL 3

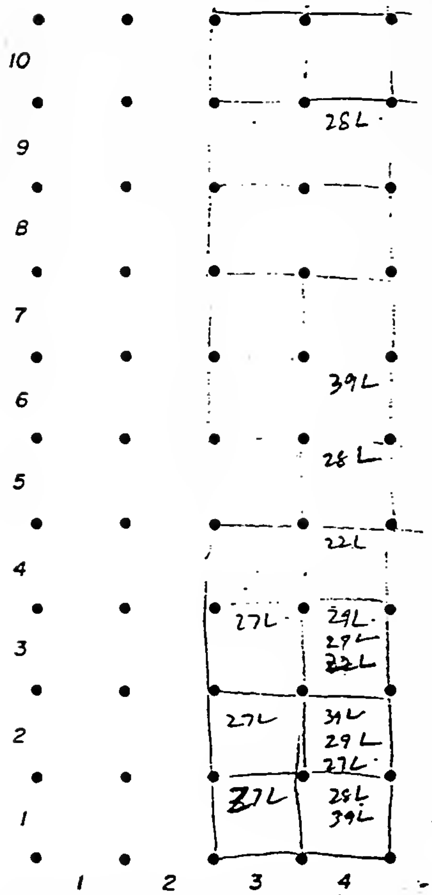
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-31 SULLIVAN   SECTION SB

DATE 5/15/92   SAMPLE UNIT 6

SURVEYED BY Z. AHMED   SLAB SIZE 12' x 20'



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Smal.
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	L			2
22	L	2	10	8
27	L	5	25	2
28	L	3	15	8
29	L	2	10	2
39	L	2	10	2
q=2	TOTAL DEDUCT VALUE			24
CORRECTED DEDUCT VALUE (CDV)				19

PCI = 100 - CDV = 81

RATING = V. Good.

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

X-Drain on both sides.

DA FORM 5145-R, NOV 82

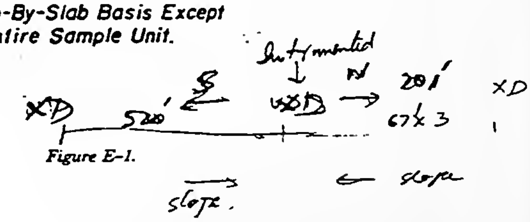


Figure E-1.

397-550 0 - 83 - 11 : QL 3

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-30 LAPORTE SECTION EB WB
DATE 10/13/91 SAMPLE UNIT 1
SURVEYED BY Z. AHMED, H. COSNO AREA OF SAMPLE 24' x 100'

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:

EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

	TYPE	7	10				
QUANTITY & SEVERITY		100' L	24' L				
		15 L	15 L				
		1	10' L				
			100' L				
TOTAL SEVERITY	L	115	149				
	M						
	H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	4.8	L	7
10	6.2	L	13
q=	TOTAL DEDUCT VALUE		20
CORRECTED DEDUCT VALUE (CDV)			10

PCI = 100 − CDV = 90

RATING = Excellent

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

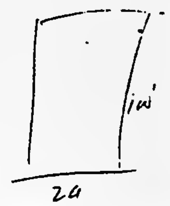
Overall PCI = 86.3. Rating Excellent

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-30 LAPORTE SECTION WB
DATE 10/13/91 SAMPLE UNIT 2
SURVEYED BY Z. AHMED ; H. COSMO AREA OF SAMPLE 24'x100'

Distress Types		SKETCH:
1. Alligator Cracking	*10. Long & Trans Cracking	
2. Bleeding	11. Patching & Util Cut Patching	
3. Block Cracking	12. Polished Aggregate	
*4. Bumps and Sags	*13. Potholes	
5. Corrugation	14. Railroad Crossing	
6. Depression	15. Rutting	
*7. Edge Cracking	16. Shoving	
*8. Jt Reflection Cracking	17. Slippage Cracking	
*9. Lane/Shldr Drop Off	18. Swell	
	19. Weathering and Raveling	



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	10	7					
QUANTITY & SEVERITY	10' L	15 L					
	24 L	24 L					
		100 L					
		35 L					
TOTAL SEVERITY L	34	174					
M							
H							

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	1.4	L	3.5
10	7.3	L	14
q=	TOTAL DEDUCT VALUE		17.5
CORRECTED DEDUCT VALUE (CDV)			17.5

PCI = 100 − CDV = 82.5

RATING = V. Good

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

ASPHALT PAVEMENT INSPECTION SHEET

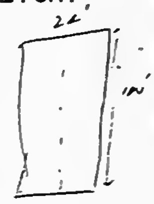
For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-30 LAPORTE SECTION WB
DATE 10/23/91 SAMPLE UNIT 3
SURVEYED BY I. AHMED; U. COSMO AREA OF SAMPLE 24×100

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

	TYPE →	10	7	8			
QUANTITY & SEVERITY		12L	3L	24			
		22L					
		18L					
		3L					
		~~24~~ 15L					
		15L					
		6L					
TOTAL SEVERITY	L	90	3	24			
	M						
	H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	0.1	L	0
8	1	L	2
10	3.8	L	9
q=	TOTAL DEDUCT VALUE		11
CORRECTED DEDUCT VALUE (CDV)			11

PCI = 100 − CDV = 89

RATING = Excellent

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-30 LAPORTE SECTION WB
DATE 10/13/91 SAMPLE UNIT 4
SURVEYED BY Z. AHMED; H. COSMO AREA OF SAMPLE 24 ... IN

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:

150

22

EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	10	7	8			
QUANTITY & SEVERITY	24L	60L	24L			
	10L					
	3L					
	30L					
	100L					
	15L					
TOTAL SEVERITY L	179	60	24			
TOTAL SEVERITY M						
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	2.5	L	4
8	1	L	2
10	7.5	L	14
q=	TOTAL DEDUCT VALUE		20
CORRECTED DEDUCT VALUE (CDV)			20

PCI = 100 − CDV = 80

RATING = V. Good

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-30 LAPORTE SECTION WB
DATE 10/13/91 SAMPLE UNIT 5
SURVEYED BY [illegible] AREA OF SAMPLE [illegible]

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:

EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	7	10				
QUANTITY & SEVERITY	30 L	24 L				
	50 L	6 L				
	8 L	8 L				
TOTAL SEVERITY L	86	38				
TOTAL SEVERITY M						
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	3.6	L	6
10	1.6	L	4
q=	TOTAL DEDUCT VALUE		10
CORRECTED DEDUCT VALUE (CDV)			10

PCI = 100 − CDV = 90

RATING = Excellent

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-31 BYPASS . SOUTH BEND SECTION NB

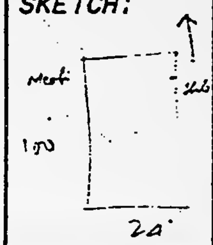
DATE 8/17/9: SAMPLE UNIT 1

SURVEYED BY Z. AHMED AREA OF SAMPLE 24 x 1000'

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	8	10	7			
QUANTITY & SEVERITY	22 L	100 L	50 L			
	100 L	12 L	50 M			
	20 L	6 L	6 L			
TOTAL SEVERITY L	142	118	56			
TOTAL SEVERITY M			50			
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	2.33	L	4
7	2.08	M	12
8	6.0	L	10
10	4.91	L	11
q= 3	TOTAL DEDUCT VALUE		37
CORRECTED DEDUCT VALUE (CDV)			23

PCI = 100 − CDV = 77

RATING = V. Good.

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

Overall Mean CDV . 80.2.
Rating :- Very Good

Comments:-
Lin ... 1/8" max depth

The section chosen was 1000 ft length x 24' wide, corresponding to the area around the instrumented site.

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-31 BYPASS. SOUTH BEND SECTION NB

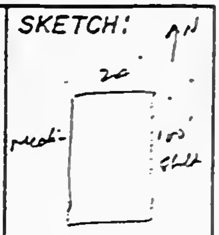
DATE 8/17/91 SAMPLE UNIT 2

SURVEYED BY I. AHMED AREA OF SAMPLE 2400 sf

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	7	8	10	1		
QUANTITY & SEVERITY	75L	2x24L	4L	4x2L		
	25M	100L	100L			
TOTAL SEVERITY L	75	148	104	8		
TOTAL SEVERITY M	25					
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
1	0.33	L	5
7	3.1	L	5
7	1.0	M	8
8	6.17	L	11
10	4.33	L	8
q= 2	TOTAL DEDUCT VALUE		37
CORRECTED DEDUCT VALUE (CDV)			29

PCI = 100 − CDV = 71

RATING = V. Good

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

Comment

The main distress seem to be edge cracking & reflection cracking

ASPHALT PAVEMENT INSPECTION SHEET

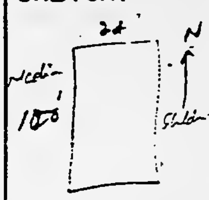
For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-31 BYPASS, SOUTH BEND SECTION N13
DATE 8/17/91 SAMPLE UNIT 3
SURVEYED BY Z-AHMED AREA OF SAMPLE 2400 s.f.

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

	TYPE →	7	8	10			
QUANTITY & SEVERITY		100L	150L	5L			
		4L	24L				
			24L				
TOTAL SEVERITY	L	104	148	5			
	M						
	H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	4.3	L	8
8	6.2	L	11
10	0.21	L	1
q= 2	TOTAL DEDUCT VALUE		20
CORRECTED DEDUCT VALUE (CDV)			15

PCI = 100 − CDV = 85

RATING = Excellent

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-31 Bypass [illegible] SECTION NB

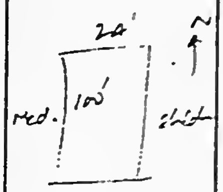
DATE 8/17/91 SAMPLE UNIT 2

SURVEYED BY Z. AHMED AREA OF SAMPLE 2400 sft

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	7	8	10				
QUANTITY & SEVERITY	100L	24L	55L				
	3L	100L	12L				
		24L	10L				
			12L				
TOTAL SEVERITY L	103	148	89				
M							
H							

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	4.3	L	8
8	6.2	L	11
10	3.7	L	8
q= 3	TOTAL DEDUCT VALUE		27
CORRECTED DEDUCT VALUE (CDV)			16

PCI = 100 − CDV = 84

RATING = V. Good

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Comments: –

Figure E-2

ASPHALT PAVEMENT INSPECTION SHEET

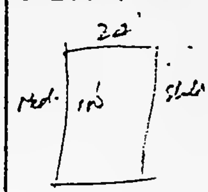
For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-31 BYPASS ; SOUTH BEND SECTION NB
DATE 8/17/91 SAMPLE UNIT 5
SURVEYED BY Z. AHMED AREA OF SAMPLE 2400 SF

Distress Types

1. Alligator Cracking	*10. Long & Trans Cracking
2. Bleeding	11. Patching & Util Cut Patching
3. Block Cracking	12. Polished Aggregate
*4. Bumps and Sags	*13. Potholes
5. Corrugation	14. Railroad Crossing
6. Depression	15. Rutting
*7. Edge Cracking	16. Shoving
*8. Jt Reflection Cracking	17. Slippage Cracking
*9. Lane/Shldr Drop Off	18. Swell
	19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE	10	7	8			
QUANTITY & SEVERITY	8L	100L	100L			
	80L	30L	24L			
	~~3r~~		24L			
TOTAL SEVERITY L	88	130	148			
M						
H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	5.4	L	8
8	6.2	L	11
10	3.67	L	8
q= 3	TOTAL DEDUCT VALUE		27
CORRECTED DEDUCT VALUE (CDV)			16

PCI = 100 − CDV = 84

RATING = V-Good.

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

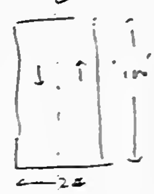
BRANCH SR-9, NOBLE
DATE 9/12/91
SURVEYED BY Z. AHMED

SECTION b/w Morrison & Allison
SAMPLE UNIT 1
AREA OF SAMPLE 2400 sft

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH: not to scale



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	17	7				
QUANTITY & SEVERITY	3'x9' L	50 L				
		50 L				
TOTAL SEVERITY L	0.28	100				
M						
H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	4.17	L	
17	0.01	L	
q=	TOTAL DEDUCT VALUE		
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 − CDV =

RATING =

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Avg. PCI = 94.56
Avg. Rating = Excellent

Figure E-2

Comments:- Long long crack @ ~~center of~~ mid-width of the lane has been sealed and is o.k.

ASPHALT PAVEMENT INSPECTION SHEET

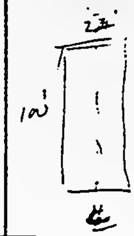
For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-9 NOBLE SECTION b/w Merriam & Albion
DATE 9/12/91 SAMPLE UNIT 2
SURVEYED BY Z.A. AREA OF SAMPLE 2400 sft

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



↑ N of UD

EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →		17	7				
QUANTITY & SEVERITY		12'x3/8" L	11' L				
TOTAL SEVERITY	L	0.375	11				
	M						
	H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	0.46	L	
17	0.02	L	
q=	TOTAL DEDUCT VALUE		
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 − CDV =

RATING =

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-9 NOBLE SECTION b/w Morrian & Albion
DATE 9/12/91 SAMPLE UNIT 3
SURVEYED BY Z. AHMED AREA OF SAMPLE 2400 S.F.

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:

EXISTING DISTRESS TYPE. QUANTITY & SEVERITY

	TYPE →	7					
QUANTITY & SEVERITY		100' L.					
TOTAL SEVERITY	L	100					
	M						
	H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	4.17	L	
q=	TOTAL DEDUCT VALUE		
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 − CDV =

RATING =

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-9 NOBLE   SECTION b/w Morrisan & Albion

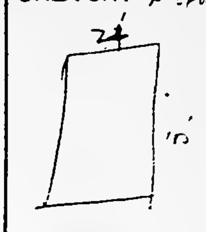
DATE 9/12/91   SAMPLE UNIT 4

SURVEYED BY Z. AHMED   AREA OF SAMPLE 240 sft

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH: N-S



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	7					
QUANTITY & SEVERITY	24 M					
	100 L					
TOTAL SEVERITY L	100					
TOTAL SEVERITY M	24					
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	4.17	L	
7	1.0	M	
q=	TOTAL DEDUCT VALUE		
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 − CDV =

RATING =

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

Comments:— Med. Sev. Edge Cracking @ pt. where ~~[illegible]~~ tractor entrance from farm to SR-9.

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-9 NOBLE — SECTION b/w [illegible]

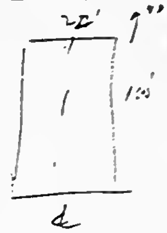
DATE 9/12/91 — SAMPLE UNIT 5

SURVEYED BY Z. AHMED — AREA OF SAMPLE 2400 sf

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
4. Bumps and Sags *
5. Corrugation
6. Depression
7. Edge Cracking *
8. Jt Reflection Cracking *
9. Lane/Shldr Drop Off *
10. Long & Trans Cracking *
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes *
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH: not [illegible]



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	7					
QUANTITY & SEVERITY	10 L.					
	100 L.					
TOTAL SEVERITY L	110					
M						
H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	4.58	L	
q=	TOTAL DEDUCT VALUE		
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 − CDV =

RATING =

Transverse 60' behind @ 660' from UD NB

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

Comment. – The edge cracking looks more like a breaking pt. b/w the old pavt side and the new 1/4" overlay.

\# Seal Coating has been done on both lanes where it seems a continuous long. crack had formed

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-9 / NOBLE SECTION b/w Morrison & Albion

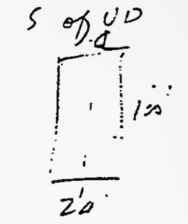
DATE 9/12/91 SAMPLE UNIT 6

SURVEYED BY Z. AHMED AREA OF SAMPLE 2400 sft

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
4. ✱ Bumps and Sags
5. Corrugation
6. Depression
7. ✱ Edge Cracking
8. ✱ Jt Reflection Cracking
9. ✱ Lane/Shldr Drop Off
10. ✱ Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. ✱ Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	7					
QUANTITY & SEVERITY	70L					
TOTAL SEVERITY L	70					
M						
H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	2.92	L	
q=	TOTAL DEDUCT VALUE		
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 − CDV =

RATING =

✱ All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Comments
Cut & fill section
Rolling Terrain
Loose Edge Cracking on fill side

Figure E-2

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-9, NOBLE SECTION b/w [illegible] v Albion

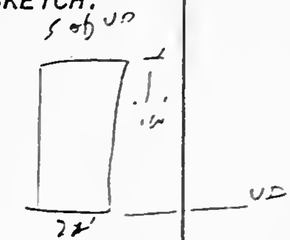
DATE 9/12/91 SAMPLE UNIT 7

SURVEYEDBY Z. AHMED AREA OF SAMPLE 2400 sft

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	7					
QUANTITY & SEVERITY	200 L					
	100 L					
TOTAL SEVERITY L	200					
M						
H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	8.33	L	
q=	TOTAL DEDUCT VALUE		
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 − CDV =

RATING =

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

Comments:-
UD at 200' from drain instrumented. free flowing. S of previous drain
Cut & fill section
Drain on Cut side-

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-9, NOBLE SECTION ______

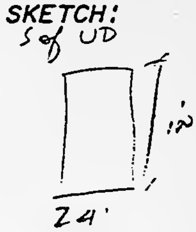
DATE 9/12/91 SAMPLE UNIT 8

SURVEYED BY Z. AHMED AREA OF SAMPLE ______

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	7					
QUANTITY & SEVERITY	54' L.					
TOTAL SEVERITY L	54					
TOTAL SEVERITY M						
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	2.25	L	
q=	TOTAL DEDUCT VALUE		
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 − CDV = ______

RATING = ______

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

Cut & fill section

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SA-9. NOBLE　　SECTION

DATE 9/12/91　　SAMPLE UNIT 5

SURVEYED BY Z. AHMED　　AREA OF SAMPLE

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH: S of UD

EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →		7					
QUANTITY & SEVERITY		30L					
TOTAL SEVERITY	L	30					
	M						
	H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	1.25	L	
q=	TOTAL DEDUCT VALUE		
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 - CDV =

RATING =

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

~~Comments~~: Cut section on both sides. Surface drain present

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SA - 9, NOBLE   SECTION ______

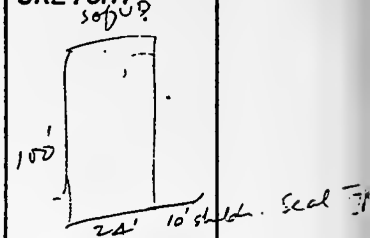
DATE 91/21/91   SAMPLE UNIT 10

SURVEYED BY Z. AHMED   AREA OF SAMPLE ______

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE	10					
QUANTITY & SEVERITY	4' L					
TOTAL SEVERITY L	4					
M						
H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
10	0.17	L	
q=	TOTAL DEDUCT VALUE		
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 - CDV = ______

RATING = ______

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

Comments -
~~[illegible]~~ Trans. Crack propagating from Shldr onto pavement
Cut section on both sides

ASPHALT PAVEMENT INSPECTION SHEET

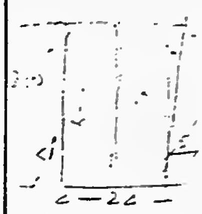
For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH 1 Toward W. LAF SECTION SR-43
DATE 7/9/90 SAMPLE UNIT 1
SURVEYED BY [illegible] AREA OF SAMPLE 4800 sft

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	9	19				
QUANTITY & SEVERITY	250' M	30 x 20'				
TOTAL SEVERITY L						
TOTAL SEVERITY M	M	L				
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
9	4.16	M	9
19	12.5	L	6
q=	TOTAL DEDUCT VALUE		15
CORRECTED DEDUCT VALUE (CDV)			10

PCI = 100 − CDV = 90

RATING = Excellent

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

ASPHALT PAVEMENT INSPECTION SHEET

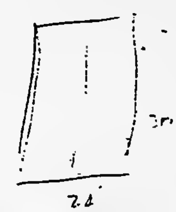
For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH 1 Touch 'N LAT SECTION SR-43
DATE 7/9/90 SAMPLE UNIT 2
SURVEYED BY 2 ... AREA OF SAMPLE 4800 sf

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	9		15	10		
QUANTITY & SEVERITY	200' L		3'x5' L	550' L		
	25 M			24x8# L		
TOTAL SEVERITY L	200		15	692		
TOTAL SEVERITY M	25					
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
9	4.17	L	6
9	0.52	M	4
15	0.31	L	2
10	14.4	L	31
q=	TOTAL DEDUCT VALUE		43
CORRECTED DEDUCT VALUE (CDV)			30

PCI = 100 − CDV = 70

RATING = GOOD to V. GOOD

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

ASPHALT PAVEMENT INSPECTION SHEET

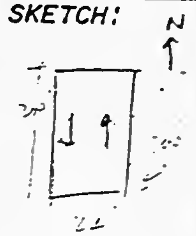
For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH 1 SECTION SR-43
DATE 9/7/90 SAMPLE UNIT 3
SURVEYED BY Z.A AREA OF SAMPLE 4800 SF

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

	TYPE → 9			10	13	19
QUANTITY & SEVERITY	60' M			550 L	1	[illegible] L
	40 L					
				24'x3' L		
				TRANS		
TOTAL SEVERITY L	40			572	1	600
TOTAL SEVERITY M	60					
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
9	0.83	L	2
9	1.25	M	5
10	11.92	L	14
13	0.02	L	6
19	12.5	L	6
q=	TOTAL DEDUCT VALUE		33
CORRECTED DEDUCT VALUE (CDV)			18

PCI = 100 − CDV = 82

RATING = V. GOOD

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH 1 SECTION SC-1

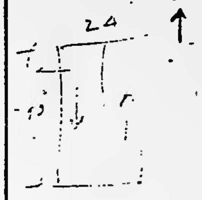
DATE 7/9/92 SAMPLE UNIT 4

SURVEYED BY J-A. AREA OF SAMPLE 4800

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH: N



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE	9	9	10	13	19	7
QUANTITY & SEVERITY	200' M	70' L	200 L	1 L	12 L	7 M
			160 L			
TOTAL SEVERITY L		70	360	1	12	
M	200					7
H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	0.15	M	4
9	1.46	L	3
9	4.17	M	9
10	15.0	L	20
13	0.02	L	6
19	0.25	L	1
q=	TOTAL DEDUCT VALUE		43
CORRECTED DEDUCT VALUE (CDV)			25

PCI = 100 − CDV = 75

RATING = V. GOOD

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH 1 SECTION SR-43
DATE 7/9/90 SAMPLE UNIT 5
SURVEYED BY Z.A. AREA OF SAMPLE 4800

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH: N 200 24

EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE	9	10	10	2	15	
QUANTITY & SEVERITY	200 L	200+12x2x8	48 M	200x2.5 L	200x3 L	
		L				
TOTAL SEVERITY L	200	592		500	600	
M			48			
H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
2	10.42	L	3
9	4.17	L	6
10	12.33	L	19
10	1.0	M	9
15	12.5	L	29
q=	TOTAL DEDUCT VALUE		66
CORRECTED DEDUCT VALUE (CDV)			37

PCI = 100 − CDV = 63

RATING = GOOD

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH 1 SECTION SR-43 TIPPECANOE

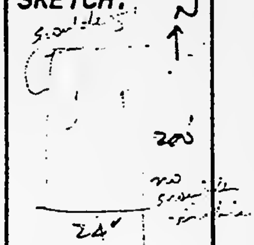
DATE 7/9/90 SAMPLE UNIT 6

SURVEYED BY Z.A. AREA OF SAMPLE 4800

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE. QUANTITY & SEVERITY

TYPE	2	7	9	1	15	10
QUANTITY & SEVERITY	200×8' M	40' L	200 L	200×2.5 L	200' M	35' L
TOTAL SEVERITY L		40	200	500		35
TOTAL SEVERITY M	1600				200	
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
1	10.41	L	33
2	33.33	M	22
7	0.83	L	3
9	4.17	L	6
10	0.73	L	1
15	4.17	M	32
q=	TOTAL DEDUCT VALUE		97
CORRECTED DEDUCT VALUE (CDV)			55

PCI = 100 − CDV = 45

RATING = FAIR

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

ASPHALT PAVEMENT INSPECTION SHEET

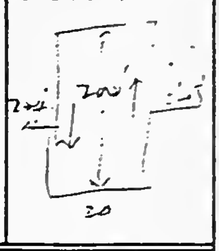
For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH 2 SECTION SR-43
DATE 7/17/92 SAMPLE UNIT 1
SURVEYED BY Z. A. U. K. AREA OF SAMPLE 4800 ft²

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	9	10		9		
QUANTITY & SEVERITY	90 M	TRANS		60' L		
		12×22' L				
		400 L				
TOTAL SEVERITY L		664		60		
TOTAL SEVERITY M	90					
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
9	1.25	L	3
9	1.88	M	6
10	13.83	L	20
q=	TOTAL DEDUCT VALUE		29
CORRECTED DEDUCT VALUE (CDV)			22

PCI = 100 − CDV = 78

RATING = V. GOOD

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

Gravely Shoulder
Water Ponding on some sections of shoulder after rainfall

ASPHALT PAVEMENT INSPECTION SHEET

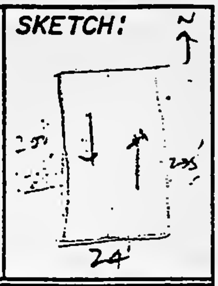
For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH 2 SECTION SR - 22
DATE 7/12/90 SAMPLE UNIT 2
SURVEYED BY ______ AREA OF SAMPLE 2800 sf

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE	19	2	10			
QUANTITY & SEVERITY	200 × 1' L	300' × 1' L	9' M			
			104 L			
TOTAL SEVERITY L	200	300	104			
M			9			
H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
2	6.25	L	2
10	2.17	L	5
10	0.19	M	1
19	4.17	L	3
q=	TOTAL DEDUCT VALUE		11
CORRECTED DEDUCT VALUE (CDV)			11

PCI = 100 − CDV = 89

RATING = V. GOOD

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

* Water from the slopes come directly onto the pavement resulting in raveling

ASPHALT PAVEMENT INSPECTION SHEET

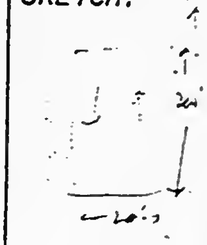
For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH 2 SECTION SR - 2?
DATE 7/17/90 SAMPLE UNIT 3
SURVEYED BY ?.A. ?.? AREA OF SAMPLE 4800 sft

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	9	15	19	9	10	
QUANTITY & SEVERITY	300' L	20'×1' L	100'×1' L	60' M	6×24' L	
TOTAL SEVERITY L	300	20	100		144	
M				60		
H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
9	6.25	L	8
9	1.25	M	5
10	3.0	L	7
15	0.42	L	3
19	2.08	L	2
q=	TOTAL DEDUCT VALUE		25
CORRECTED DEDUCT VALUE (CDV)			18

PCI = 100 − CDV = 82

RATING = V. Good

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

* Open ditch on the side of Wabash Hospital.

* Long & Trans Cracks have opened up from seal coatings.

ASPHALT PAVEMENT INSPECTION SHEET

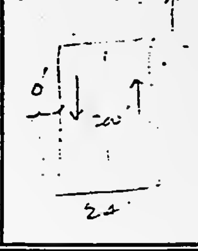
For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH 2 SECTION SR-23
DATE 7/17/90 SAMPLE UNIT 4
SURVEYED BY Z.A. H.H. AREA OF SAMPLE 4800 s.f.

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	19	9	9	13	7	
QUANTITY & SEVERITY	200 × 3 M	150' M	200' L	2 L	30' L	
TOTAL SEVERITY L			200	2	30	
M	600	150				
H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	0.625	L	3
9	4.17	L	6
9	2.08	M	6
13	0.04	L	11
19	12.5	M	6
q=	TOTAL DEDUCT VALUE		32
CORRECTED DEDUCT VALUE (CDV)			13

PCI = 100 − CDV = 87

RATING = V. Good

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

× Cross Drain Pipe 24" Ø at this section
+ Grass at at the edge of Pvt. shoulder not visible

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH 2 SECTION SR-33
DATE [illegible] SAMPLE UNIT 5
SURVEYED BY [illegible] AREA OF SAMPLE 4800 [illegible]

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:

EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	19	19	2	15		
QUANTITY & SEVERITY	[illegible] L	200' x 1' M	200' x 1' L	400' L		
TOTAL SEVERITY L	3600		200	400		
TOTAL SEVERITY M		200				
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
2	4.17	L	1
15	8.33	L	26
19	75.0	L	14
19	4.17	M	12
q=	TOTAL DEDUCT VALUE		53
CORRECTED DEDUCT VALUE (CDV)			33

PCI = 100 − CDV = 67

RATING = GOOD

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

* The South Bound has open ditch at the shoulder edge lined with 6" size stone.
* The North side has water standing on the shoulder due to water seeping from high ground of an adj. property.

* Shoulder gravel has been washed away exposing it [illegible] and [illegible]
* Rutting along the wheel path SB.

ASPHALT PAVEMENT INSPECTION SHEET

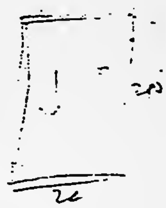
For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH	2	SECTION	SR-23
DATE	7/11/00	SAMPLE UNIT	6
SURVEYED BY	J. A. - K. H.	AREA OF SAMPLE	~~28~~00 sf

Distress Types

1. Alligator Cracking	*10. Long & Trans Cracking
2. Bleeding	11. Patching & Util Cut Patching
3. Block Cracking	12. Polished Aggregate
*4. Bumps and Sags	*13. Potholes
5. Corrugation	14. Railroad Crossing
6. Depression	15. Rutting
*7. Edge Cracking	16. Shoving
*8. Jt Reflection Cracking	17. Slippage Cracking
*9. Lane/Shldr Drop Off	18. Swell
	19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	7	9	19	15	10	
QUANTITY & SEVERITY	170' M	150' L	240'×4' M	70'×2' L	25' L	
			20'×5' M		64 L	
TOTAL SEVERITY L		150		140	89	
M	170		960			
H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	3.54	M	18
9	3.125	L	5
10	1.85	L	4
15	2.92	L	16
19	20	M	24
q=	TOTAL DEDUCT VALUE		67
CORRECTED DEDUCT VALUE (CDV)			43

PCI = 100 − CDV = 57

RATING = GOOD

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2.

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-63 VERMILLION SECTION SB
DATE 10/22/01 SAMPLE UNIT 1
SURVEYED BY Z. Ahmed / H. Cosm AREA OF SAMPLE 24' x 100'

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:

EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	10	7	1	3	15	[illegible]
QUANTITY & SEVERITY	8L	92L	2'x40' L	40L	10'x2' M	[illegible] L
	20L	39L			80x2' M	
	27L				10'x2' H	
	56L				10'x2' H	
	10L					
	100M					
	25L					
TOTAL SEVERITY L	246	133	80	40		400
M					360	
H					40	

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
10	10.25	L	
7	5.54	L	
1	3.33	L	
3	1.66	L	
15	15	M	
15	1.67	H	
19	16.67	L	
q=	TOTAL DEDUCT VALUE		
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 − CDV =

RATING =

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Avg. PCI = 36.84
Avg. Rating = Poor

Figure E-2

* Low Severity of Alligator & Block Cracking entire length of the pavement

* Section . South of UD
* The Inner Lane has distress ranging from block cracking to long. cracking but has no rut. The outer lane has ruts along both wheel paths with higher intensity on the inner wheel path

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-63. VERMILLION SECTION SB
DATE 10/22/91 SAMPLE UNIT 2
SURVEYED BY 2. [illegible] /H. COSMO AREA OF SAMPLE 24' x 75'

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:

EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	7	10	3	15	19	
QUANTITY & SEVERITY	100 L.	18 L	100' x 12'	90 x 3' M	200' x 2' L	
		20 L.		10 x 3' H.		
		30 L.		10' x 3' H.		
		40 L		20 x 3 H		
				70' x 3M		
TOTAL SEVERITY L	100	108	1200		400	
M				480		
H.				120		

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
7	4.2	L	
10	4.5	L	
3	50	L	
15	20	M	
15	5	H	
19	16.7	L	
q=	TOTAL DEDUCT VALUE		
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 - CDV =

RATING =

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

* Section South of VD

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-67 [illegible] SECTION SB
DATE 10/22/[illegible] SAMPLE UNIT 3
SURVEYED BY [illegible] AREA OF SAMPLE 24×[illegible]

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
*4. Bumps and Sags
5. Corrugation
6. Depression
*7. Edge Cracking
*8. Jt Reflection Cracking
*9. Lane/Shldr Drop Off
*10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
*13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:

EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	15	3	10	7	19	
QUANTITY & SEVERITY	100×3' M	12'×40' L	20' M	6 L	10'×2' L	
	90'×3' M		20' L	9 L		
	10'×3' H		10 L	15 L		
			10 L	18 L		
			20 L	10 L		
			10 L			
TOTAL SEVERITY L	[illegible]	480	70	58	200	
M	570		20			
H	30					

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
15	23.8	M	
15	1.3	H	
3	20	L	
10	2.9	L	
10	0.83	H	
7	2.4	L	
19	8.3	L	
q=	TOTAL DEDUCT VALUE		
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 − CDV =

RATING =

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

* Section is on an embankment. & The ditch [illegible]
— 50 to 60 feet [illegible].
* Section south of [illegible]

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-53 VERM SECTION SB

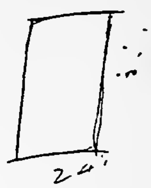
DATE 10/22/91 SAMPLE UNIT 4

SURVEYED BY 2-AHMEA/H.OSMO AREA OF SAMPLE 24'x 95'

Distress Types

1. Alligator Cracking	*10. Long & Trans Cracking
2. Bleeding	11. Patching & Util Cut Patching
3. Block Cracking	12. Polished Aggregate
*4. Bumps and Sags	*13. Potholes
5. Corrugation	14. Railroad Crossing
6. Depression	15. Rutting
*7. Edge Cracking	16. Shoving
*8. Jt Reflection Cracking	17. Slippage Cracking
*9. Lane/Shldr Drop Off	18. Swell
	19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE. QUANTITY & SEVERITY

TYPE →	15	10	3	19	7	
QUANTITY & SEVERITY	100'x3' M	3' M	45'x6' M	10'x2' L	9' L	
	100'x3' M	6' L				
		5' L				
		20' L				
		10' M				
		10' L				
		15 L				
		100 M				
		30 L				
TOTAL SEVERITY L		86		200	9	
TOTAL SEVERITY M	600	113	270			
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
15	25	M	
10	3.6	L	
10	4.7	M	
3	11.3	M	
19	8.3	L	
7	0.4	L	
q=	TOTAL DEDUCT VALUE		
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 − CDV =

RATING =

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

* Sample Unit ~~Section~~ or a Cut Section that ~~[illegible]~~ unit of UD

Figure E-2.

ASPHALT PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH SR-62, VERMILLION — SECTION 5A

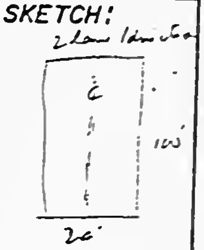
DATE 10/22/91 — SAMPLE UNIT 5

SURVEYED BY Z. AHMED/H. COSMO — AREA OF SAMPLE 20'×100'

Distress Types

1. Alligator Cracking
2. Bleeding
3. Block Cracking
4. * Bumps and Sags
5. Corrugation
6. Depression
7. * Edge Cracking
8. * Jt Reflection Cracking
9. * Lane/Shldr Drop Off
10. * Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. * Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering and Raveling

SKETCH:



EXISTING DISTRESS TYPE, QUANTITY & SEVERITY

TYPE →	15	7	10	1	15	
QUANTITY & SEVERITY	60'×3' H.	33 L.	12' L.	20'×1'-L	100'×2' L	
	40'×3' M.		50 L.			
	100'×3' M		34' L.			
			30' L			
			10' M			
			100' M.			
TOTAL SEVERITY L		33	126	20	200	
TOTAL SEVERITY M	420		110			
TOTAL SEVERITY H	180					

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
15	17.5	M	
7	1.4	L.	
10	5.25	L.	
10	4.6	M.	
15	7.5	H.	
1	0.8	L.	
q=	TOTAL DEDUCT VALUE		
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 − CDV =

RATING =

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured In Number of Potholes.

DA FORM 5146-R, NOV 82

Figure E-2

* Unit ~~South~~ North of UD.

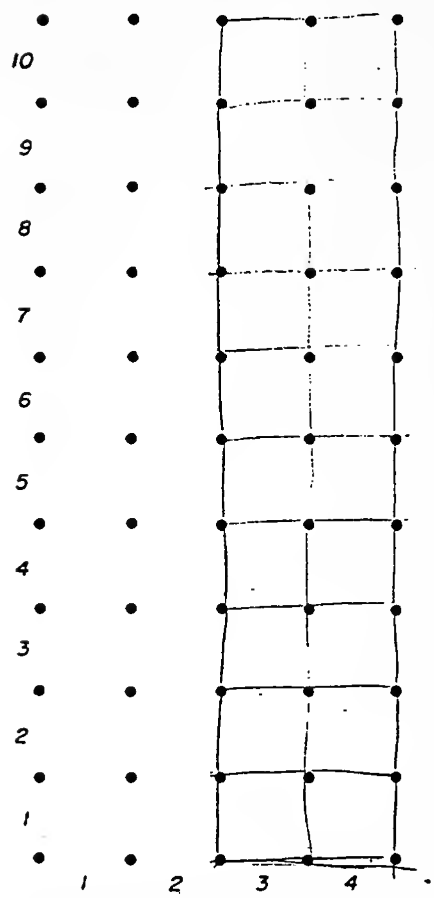
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-36 [illegible] SECTION 1 WB

DATE 5/13/92 SAMPLE UNIT 1

SURVEYED BY ? [illegible] SLAB SIZE 12' × 18'



EB

Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Smal.
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, U Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	L			2
q=	TOTAL DEDUCT VALUE			2
CORRECTED DEDUCT VALUE (CDV)				2

PCI = 100 − CDV = 98

RATING = EXCELLENT

4 Units East of CD

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

OVERALL PCI = 96.6
RATING = EXCELLENT

No Distress Present
Except 26 (Pvt-Shldr Joint Cracks)
There is no seal b/w Pvt & Shldr at the joint

Figure E-1.

Longitudinal and Transverse joints are sealed and in good condition.
Grooved pavement and inclined joints.
Overall Pavement Section is in very good condition.

392-550 0 - 83 - 21 : QL 3

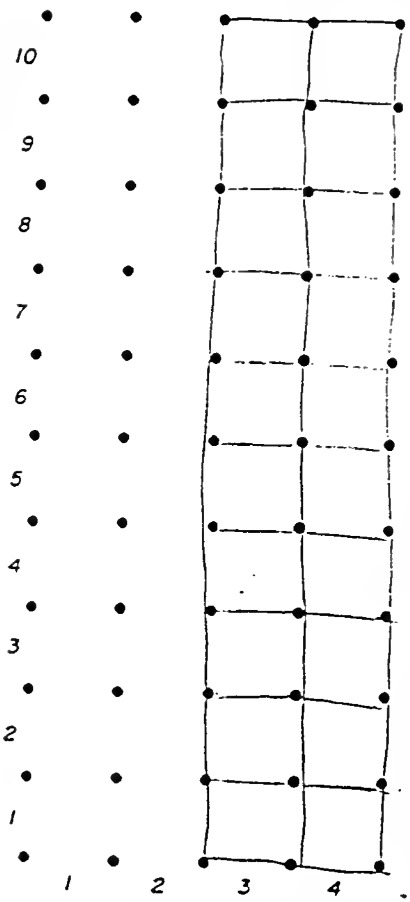
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-36 HENDRICKS   SECTION WB

DATE 5/13/92   SAMPLE UNIT 2

SURVEYED BY Z. AHMED   SLAB SIZE 12' x 18'



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Smal.
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, U Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	L			2
q=	TOTAL DEDUCT VALUE			2
CORRECTED DEDUCT VALUE (CDV)				2

PCI = 100 - CDV = 98

RATING = EXCELLENT

No Distress Except Pvt-Shldr Jnt. Transverse Crack in Shldr every 30'
Type I Seal Coat on ...

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Figure E-1.

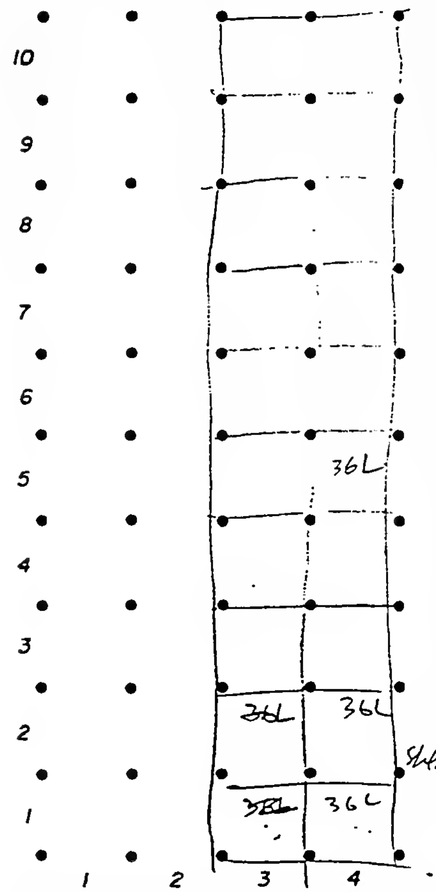
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH: US-36 HENDRICKS SECTION: WB

DATE: 5/13/92 SAMPLE UNIT: 3

SURVEYED BY: Z. AHMED SLAB SIZE: 12'x(18'-19')



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Smal.
31. Polished Aggregate.
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, U Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*				2
36	L	3	15	7
q=	TOTAL DEDUCT VALUE			9
CORRECTED DEDUCT VALUE (CDV)				9

PCI = 100 - CDV = 91

RATING = EXCELLENT

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Figure E-1.

392-510 0 - 83 - 11 : QL 3

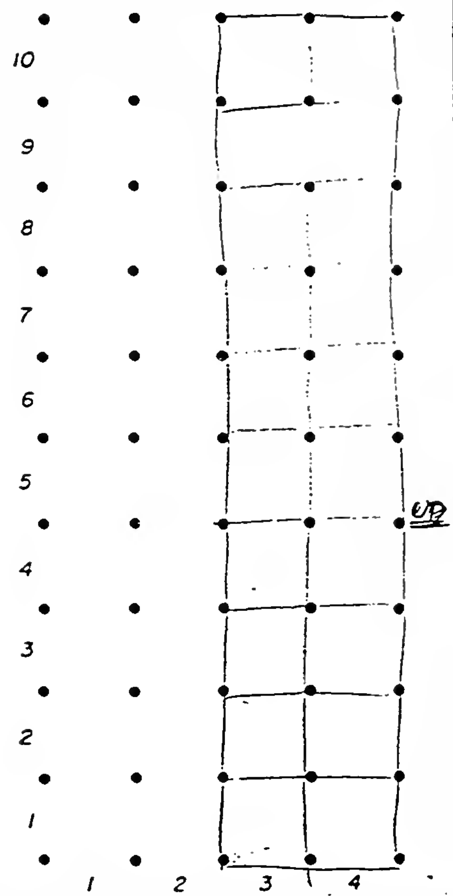
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US-36 [illegible] SECTION WB

DATE 5/12/92 SAMPLE UNIT 4

SURVEYED BY Z. AHMED SLAB SIZE 12' x 18'



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Small
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	L.			2
q=	TOTAL DEDUCT VALUE			~~98~~ 2
CORRECTED DEDUCT VALUE (CDV)				2

PCI = 100 - CDV = 98

RATING = EXCELLENT

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

UD at this section

DA FORM 5145-R, NOV 82

Figure E-1.

797-550 0 - 83 - [illegible]

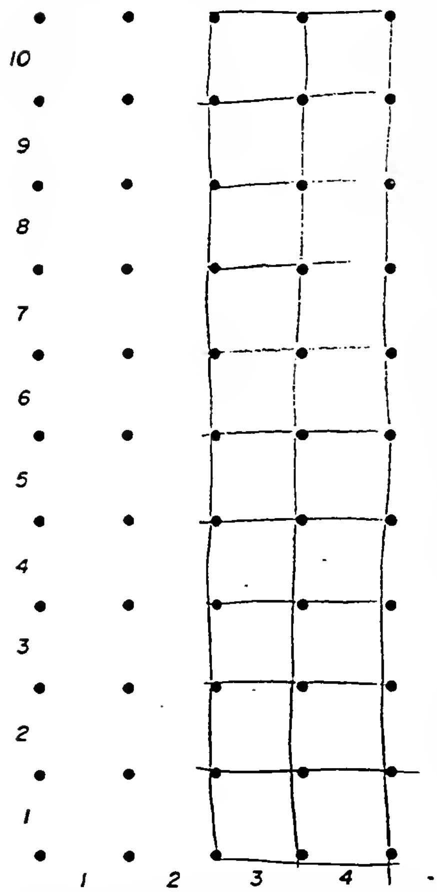
CONCRETE PAVEMENT INSPECTION SHEET

For use of this form, see TM 5-623; the proponent agency is USACE.

BRANCH US 36 HENDRICKS SECTION WB

DATE 5/13/92 SAMPLE UNIT 5

SURVEYED BY Z. AHMED SLAB SIZE 12'x(18-19)'



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Smal.
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, U Joint

DIST. TYPE	SEV.	NO. SLABS	% SLABS	DEDUCT VALUE
26*	L			2
q=	TOTAL DEDUCT VALUE			2
CORRECTED DEDUCT VALUE (CDV)				2

PCI = 100 - CDV = 98

RATING = EXCELLENT

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress26, Which Is Rated For the Entire Sample Unit.

DA FORM 5145-R, NOV 82

Figure E-1.

392-550 0 - 83 - 11 : QL 3

Appendix D
Laboratory Data on Soil-Moisture Properties

SITE DESCRIPTION

Sample Site:	US-31, NB; Hamilton County, Greenfield District; Section at Carmel near St. Vincent Hospital
Project No:	ST-F-222(9)
Pavement Type:	11" JRCP over 4" Bituminous Stabilized Subbase #5D
Joint Condition:	Unsealed
Sample Depth:	24-48 inches from surface
Parent Material:	Loamy and silty soils in glacial till
Soil Association:	L
Int. Drainage:	Well drained
Groundwater:	Not present

ROADBED SOIL PROPERTIES

Liquid Limit:	20	In-situ Density: Dry Density:	130.63 pcf 94.40 pcf
Plasticity Index:	6	In-situ Moisture:	9.0 %
AASHTO Class:	A-4(0)	Specific Gravity:	2.83
Unified Class:	SM-SC	Permeability:	2.4×10^{-6} cm/sec 6.0×10^{-3} ft/day
USDA Text. Class:	Sandy loam	Porosity:	29.3 %
% Passing #200:	47		

MOISTURE CHARACTERISTICS DATA

Suction (in bars) (in cm H_2O)	0.0 0	0.1 122	0.33 403	0.6 732	1.0 1220	3.0 3660	5.0 6100	15.0 18300
ω %	19.4	17.63	13.95	12.67	11.43	8.66	7.12	6.27
θ %	29.3	26.6	21.1	19.1	17.3	13.1	10.8	9.5
Sr, %	100.0	90.9	71.9	65.3	58.9	44.6	36.7	32.3
Se,	1.00	0.86	0.58	0.49	0.39	0.18	0.06	0.00

MODEL PARAMETER VALUES

Irreduc. Moist. Content 'θ_r': 0.095 Vol. Water Capacity '$\theta_s-\theta_r$': 0.198

Brooks & Corey:	PB_d: 52 cm	ν_d: 3.1	η: 9.2
Van Genuchten:	α: 0.008 cm^{-1}	β: 1.45	γ: 0.31

SITE DESCRIPTION

Sample Site:	SR-37, SB; Hamilton County, Greenfield District; Section at Noblesville, north of SR-32 Jct.
Project No:	F-824(3)
Pavement Type:	9½" Full Depth Asphalt over 8" #2 Aggregate Subbase
Joint Condition:	Unsealed
Sample Depth:	24-36 inches from surface
Parent Material:	Loamy silt on flood plain
Soil Association:	A
Int. Drainage:	Well drained
Groundwater:	Present

ROADBED SOIL PROPERTIES

Liquid Limit:	20	In-situ Density: Dry Density:	127.65 pcf 111.38 pcf
Plasticity Index:	6	In-situ Moisture:	13.0 %
AASHTO Class:	A-2-4(0), A-4(0)	Specific Gravity:	2.81
Unified Class:	SM-SC, SC	Permeability:	1.3×10^{-4} cm/sec 0.325 ft/day
USDA Text. Class:	Sandy loam	Porosity:	20.2 %
% Passing #200:	35		

MOISTURE CHARACTERISTICS DATA

Suction (in bars) (in cm H_2O)	0.0 0	0.1 122	0.33 403	0.6 732	1.0 1220	3.0 3660	5.0 6100	15.0 18300
ω %	11.75	10.91	8.82	7.72	7.0	4.17	3.77	2.97
θ %	20.2	18.8	15.2	13.28	12.0	7.2	6.5	5.1
Sr, %	100.0	92.9	75.1	65.7	59.6	35.5	32.1	25.3
Se,	1.0	0.90	0.67	0.54	0.46	0.14	0.09	0.00

MODEL PARAMETER VALUES

Irreduc. Moist. Content 'θ_r': 0.051 Vol. Water Capacity '$\theta_s - \theta_r$': 0.151

Brooks & Corey:	PB_d: 68.5 cm	ν_d: 3.18	η: 9.36
Van Genuchten:	α: 0.0054 cm^{-1}	β: 1.46	γ: 0.315

SITE DESCRIPTION

Sample Site:	SR-37, SB; Lawrence County, Vincennes District: Section on uphill terrain at Jct SR-58 near Bedford.
Project No:	ST-F-819(2)
Pavement Type:	10½" JRCP over 4½" Bit. Stabilized Subbase #5D
Joint Condition:	Unsealed
Sample Depth:	16-40 inches from surface
Parent Material:	Silty and clayey soils in loess and weathered limestone
Soil Association:	Q
Int. Drainage:	Moderate
Groundwater:	Not present

ROADBED SOIL PROPERTIES

Liquid Limit:	36, 52	In-situ Density: Dry Density:	123.83 pcf 99.63 pcf
Plasticity Index:	16,30	In-situ Moisture:	25.0%
AASHTO Class:	A-6(15), A-7-6(34)	Specific Gravity:	2.70, 2.82
Unified Class:	CL, CH	Permeability:	2.1×10^{-7} cm/sec 6.0×10^{-4} ft/day
USDA Text. Class:	Silty clay loam/silty loam	Porosity:	65.9 %
% Passing #200:	>50		

MOISTURE CHARACTERISTICS DATA

Suction (in bars) (in cm H_2O)	0.0 0	0.1 122	0.33 403	0.6 732	1.0 1220	3.0 3660	5.0 6100	15.0 18300
ω %	42.25	39.62	33.18	31.12	28.84	23.32	22.68	21.22
θ %	65.9	61.8	51.8	48.6	45.0	36.4	35.4	33.1
Sr, %	100.0	93.8	78.5	73.7	68.3	55.2	53.7	50.2
Se,	1.00	0.87	0.57	0.47	0.36	0.10	0.07	0.00

MODEL PARAMETER VALUES

Irreduc. Moist. Content 'θ_r': 0.331 Vol. Water Capacity 'θ_s-θ_r': 0.328

Brooks & Corey:	PB_d: 67.5 cm	v_d: 2.8	η: 8.6
Van Genuchten:	α: 0.0048 cm^{-1}	β: 1.665	γ: 0.399

SITE DESCRIPTION

Sample Site:	US-41, SB; Sullivan County, Vincennes District; Section at Farmersburg, south of Terre Haute.
Project No:	F-35(11)
Pavement Type:	10½" JPCP over 3-4 inches Bituminous Stabilized Subbase
Joint Condition:	Unsealed
Sample Depth:	29-40 inches from surface
Parent Material:	Silty soils in loess
Soil Association:	I
Int. Drainage:	Poor
Groundwater:	Not present

ROADBED SOIL PROPERTIES

Liquid Limit:	15	In-situ Density:	134.08 pcf
		Dry Density:	113.99 pcf
Plasticity Index:	17	In-situ Moisture:	16.0 %
AASHTO Class:	A-6(8)	Specific Gravity:	2.75
Unified Class:	CL	Permeability:	6 x 10^{-4} cm/sec 1.5 ft/day
USDA Text. Class:	Silty clay loam	Porosity:	51.9 %
% Passing #200:	62		

MOISTURE CHARACTERISTICS DATA

Suction (in bars)	0.0	0.1	0.33	0.6	1.0	3.0	5.0	15.0
(in cm H_2O)	0	122	403	732	1220	3660	6100	18300
ω %	31.25	28.97	23.38	21.12	17.50	15.73	13.92	12.89
θ %	51.9	48.1	38.8	35.1	29.1	26.1	23.1	21.4
Sr, %	100.0	92.7	74.82	67.58	56.0	50.34	44.54	41.25
Se,	1.00	0.88	0.57	0.45	0.25	0.15	0.06	0.00

MODEL PARAMETER VALUES

Irreduc. Moist. Content 'θ_r': 0.214 Vol. Water Capacity '$\theta_s-\theta_r$': 0.305

Brooks & Corey: PB_d: 60 cm v_d: 3.0 η: 9.0

Van Genuchten: α: 0.008 cm^{-1} β: 1.48 γ: 0.324

SITE DESCRIPTION

Sample Site:	US-30, WB; Laporte County, Laporte District Section b/w Wanatah and Hanna near KOA campground.
Project No:	F-77(18 & 20)
Pavement Type:	6" Asphalt overlay over 9" JRCP over 5" sandy subbase
Joint Condition:	Unsealed
Sample Depth:	24-35 inches from surface
Parent Material:	Sandy soils
Soil Association:	B
Int. Drainage:	Poor
Groundwater:	Not present

ROADBED SOIL PROPERTIES

Liquid Limit:	N/A	In-situ Density: Dry Density:	136.92 pcf 123.33 pcf
Plasticity Index:	NP	In-situ Moisture:	7.8 %
AASHTO Class:	A-3(0)	Specific Gravity:	2.67
Unified Class:	SP-SM	Permeability:	1.1×10^{-3} cm/sec 2.63 ft/day
USDA Text. Class:	Fine Sand	Porosity:	18.3 %
% Passing #200:	6		

MOISTURE CHARACTERISTICS DATA

Suction (in bars)	0.0	0.1	0.33	0.6	1.0	3.0	5.0	15.0
(in cm H_2O)	0	122	403	732	1220	3660	6100	18300
ω %	10.42	10.15	8.45	6.66	5.95	4.44	3.99	2.88
θ %	18.3	17.9	14.9	11.8	10.5	7.8	7.0	5.1
Sr, %	100.0	97.41	81.09	63.92	57.10	42.61	38.29	27.64
Se,	1.00	0.96	0.74	0.50	0.41	0.21	0.15	0.00

MODEL PARAMETER VALUES

Irreduc. Moist. Content 'θ_r': 0.051 Vol. Water Capacity '$\theta_s - \theta_r$': 0.132

Brooks & Corey:	PB_d: 87 cm	ν_d: 2.6	η: 8.2
Van Genuchten:	α: 0.0029 cm^{-1}	β: 1.80	γ: 0.444

SITE DESCRIPTION

Sample Site:	US-31, NB; St. Joseph County, Laporte District: Section on US-31 Bypass b/w Jct SR-2 and Mayflower Rd.
Project No:	F-720(5)
Pavement Type:	3½" Asphalt Overlay on 9" JRCP over 5" Crushed Agg. Base
Joint Condition:	Unsealed
Sample Depth:	20-42 inches from surface
Parent Material:	Loamy sand
Soil Association:	F
Int. Drainage:	Well drained
Groundwater:	Not present

ROADBED SOIL PROPERTIES

Liquid Limit:	N/A	In-situ Density: Dry Density:	115.96 pcf 103.51 pcf
Plasticity Index:	NP	In-situ Moisture:	8.0 %
AASHTO Class:	A-3(0)	Specific Gravity:	2.66
Unified Class:	SP	Permeability:	2.1 x 10^{-3} cm/sec 5.23 ft/day
USDA Text. Class:	Sand	Porosity:	12.1 %
% Passing #200:	< 1		

MOISTURE CHARACTERISTICS DATA

Suction (in bars)	0.0	0.1	0.33	0.6	1.0	3.0	5.0	15.0
(in cm H_2O)	0	122	403	732	1220	3660	6100	18300
ω %	8.25	7.71	5.67	5.25	4.62	2.91	2.83	2.74
θ %	12.1	11.3	8.3	7.7	6.8	4.3	4.2	4.0
Sr, %	100.0	93.5	68.7	63.6	56.0	35.3	34.3	33.2
Se,	1.0	0.90	0.53	0.46	0.34	0.03	0.02	0.00

MODEL PARAMETER VALUES

Irreduc. Moist. Content 'θ_r': 0.04 Vol. Water Capacity '$\theta_s - \theta_r$': 0.081

Brooks & Corey:	PB_d: 78 cm	ν_d: 2.34	η: 7.68
Van Genuchten:	α: 0.0048 cm^{-1}	β: 1.665	γ: 0.339

SITE DESCRIPTION

Sample Site:	SR-9, NB; Noble County, Fort Wayne District; Section between Albion and Merrian near Burr Oaks.
Project No:	S-412(9)
Pavement Type:	9½" Full Depth Asphalt over 6" Type P gravelly subbase
Joint Condition:	Unsealed
Sample Depth:	24-40 inches from surface
Parent Material:	Clayey soils in glacial till
Soil Association:	M
Int. Drainage:	Poor
Groundwater:	Present

ROADBED SOIL PROPERTIES

Liquid Limit:	N/A	In-situ Density: Dry Density:	131.35 pcf 110.40 pcf
Plasticity Index:	NP	In-situ Moisture:	9.70 %
AASHTO Class:	A-1-a(0)	Specific Gravity:	2.70
Unified Class:	SW	Permeability:	3.4 x 10^{-3} cm/sec 8.5 ft/day
USDA Text. Class:	Sandy/gravelly sand	Porosity:	20.3 %
% Passing #200:	< 1		

MOISTURE CHARACTERISTICS DATA

Suction (in bars)	0.0	0.1	0.33	0.6	1.0	3.0	5.0	15.0
(in cm H_2O)	0	122	403	732	1220	3660	6100	18300
ω %	11.48	11.35	9.69	8.55	7.54	5.86	5.33	4.54
θ %	20.3	20.1	17.1	15.2	13.3	10.4	9.4	8.0
Sr, %	100.0	98.9	84.4	74.5	65.7	51.0	46.4	39.5
Se,	1.0	0.98	0.74	0.58	0.43	0.19	0.11	0.00

MODEL PARAMETER VALUES

Irreduc. Moist. Content 'θ_r': 0.08 Vol. Water Capacity '$\theta_s - \theta_r$': 0.123

Brooks & Corey:	PB_d: 82 cm	v_d: 3.2	η: 9.4
Van Genuchten:	α: 0.00245 cm^{-1}	β: 1.87	γ: 0.465

SITE DESCRIPTION

Sample Site:	SR-43, NB; Tippecanoe County, Crawfordsville District. Section near US-52 overpass in W. Lafayette.
Project No:	M-6262 Force Account
Pavement Type:	6½" Asphalt over 2-3 inches Ballast mixed with road oil over 4" crushed aggregate
Joint Condition:	Unsealed (Aggregate shoulder)
Sample Depth:	24-36 inches from surface
Parent Material:	Loamy soils on flood plains
Soil Association:	A
Int. Drainage:	Moderately drained
Groundwater:	Not present

ROADBED SOIL PROPERTIES

Liquid Limit:	25	In-situ Density: Dry Density:	133.68 pcf 116.84 pcf
Plasticity Index:	10-11	In-situ Moisture:	16.0 %
AASHTO Class:	A-4(4)/A-6(5)	Specific Gravity:	2.77
Unified Class:	CL	Permeability:	5.1 x 10^{-5} cm/sec 0.128 ft/day
USDA Text. Class:	Silty loam	Porosity:	38.6 %
% Passing #200:	70		

MOISTURE CHARACTERISTICS DATA

Suction (in bars)	0.0	0.1	0.33	0.6	1.0	3.0	5.0	15.0
(in cm H_2O)	0	122	403	732	1220	3660	6100	18300
ω %	23.25	20.71	16.73	15.08	13.67	11.04	10.18	7.8
θ %	38.6	34.4	27.8	25.0	22.7	18.3	16.9	12.9
Sr, %	100.0	89.0	71.9	64.9	58.8	47.5	43.8	33.5
Se,	1.00	0.84	0.58	0.47	0.38	0.21	0.15	0.00

MODEL PARAMETER VALUES

Irreduc. Moist. Content 'θ_r': 0.129 Vol. Water Capacity 'θ_s-θ_r': 0.257

Brooks & Corey:	PB_d: 61.5 cm	ν_d: 3.0	η: 9.0
Van Genuchten:	α: 0.013 cm^{-1}	β: 1.35	γ: 0.259

SITE DESCRIPTION

Sample Site:	SR-63, SB; Vermillion County, Crawfordsville District. Section near Newport past JCT SR-71 on uphill terrain.
Project No:	ST-F-305(22)
Pavement Type:	12" Full Depth Asphalt over 4½" crushed aggregate subbase
Joint Condition:	Unsealed
Sample Depth:	26-50 inches from surface
Parent Material:	Loamy and silty soil in glacial till
Soil Association:	L
Int. Drainage:	Well drained on sloping surface
Groundwater:	Not present

ROADBED SOIL PROPERTIES

Liquid Limit:	N/A	In-situ Density: Dry Density:	132.74 pcf 121.72 pcf
Plasticity Index:	NP	In-situ Moisture:	9.76 %
AASHTO Class:	A-1-a(0)	Specific Gravity:	2.73
Unified Class:	GW	Permeability:	6 x 10^{-3} cm/sec 15 ft/day
USDA Text. Class:	stratified sand/ gravelly sand	Porosity:	29.4 %
% Passing #200:	2		

MOISTURE CHARACTERISTICS DATA

Suction (in bars)	0.0	0.1	0.33	0.6	1.0	3.0	5.0	15.0
(in cm H_2O)	0	122	403	732	1220	3660	6100	18300
ω %	20.30	19.29	14.64	13.62	11.92	9.42	8.41	7.82
θ %	29.4	27.9	21.2	19.8	17.3	13.7	12.2	11.3
Sr, %	100.0	95.0	72.2	67.1	58.7	46.4	41.4	38.5
Se,	1.00	0.92	0.55	0.46	0.33	0.13	0.05	0.00

Model Parameter Values

Irreduc. Moist. Content 'θ_r': 0.113 Vol. Water Capacity 'θ_s-θ_r': 0.181

Brooks & Corey: PB_d: 80 cm ν_d: 2.31 η: 7.62

Van Genuchten: α: 0.0048 cm^{-1} β: 1.68 γ: 0.405

SITE DESCRIPTION

Sample Site:	US-36, WB; Hendricks County, Crawfordsville District; Section near Danville just pass CR-300
Project No:	F-076-2(4)
Pavement Type:	8½" JPCP over 6" Bit. Stabilized Subbase
Joint Condition:	Unsealed
Sample Depth:	30-54 inches from surface
Parent Material:	Loamy and silty soil in glacial till
Soil Association:	L
Int. Drainage:	Poor
Groundwater:	Not present

ROADBED SOIL PROPERTIES

Liquid Limit:	23	In-situ Density: Dry Density:	130.78 pcf 111.74 pcf
Plasticity Index:	8	In-situ Moisture:	11.5%
AASHTO Class:	A-4(3)	Specific Gravity:	2.64
Unified Class:	CL	Permeability:	1.1×10^{-5} cm/sec 2.8×10^{-2} ft/day
USDA Text. Class:	Loam	Porosity:	32.8 %
% Passing #200:	58		

MOISTURE CHARACTERISTICS DATA

Suction (in bars)	0.0	0.1	0.33	0.6	1.0	3.0	5.0	15.0
(in cm H_2O)	0	122	403	732	1220	3660	6100	18300
ω %	21.75	20.11	16.82	13.45	12.89	9.99	8.52	7.14
θ %	32.8	30.4	25.4	20.3	19.5	15.1	12.9	10.8
Sr, %	100.0	92.5	77.3	61.8	59.3	45.9	39.2	32.8
Se,	1.00	0.89	0.66	0.43	0.39	0.20	0.09	0.00

MODEL PARAMETER VALUES

Irreduc. Moist. Content 'θ_r': 0.108 Vol. Water Capacity '$\theta_s - \theta_r$': 0.22

Brooks & Corey:	PB_d: 72 cm	ν_d: 2.78	η: 8.56
Van Genuchten	α: 0.00625 cm^{-1}	β: 1.502	γ: 0.334

BASE\SUBBASE #1

SOIL PROPERTIES

TYPE: FINE AGGREGATE #24

GRAIN SIZE:

% PASSING	(3/8 in.)	100
	(#4)	95-100
	(#8)	70-100
	(#16)	40-85
	(#30)	20-60
	(#50)	7-40
	(#100)	1-20
	(#200)	0-6

Density(dry): 115 pcf

Opt. Moisture: 2.5%

Sp. Gravity: 2.66

Permeability: 1.1×10^{-3} cm/sec (1.2 ft/day)

Porosity: 4.8 %

MOISTURE CHARACTERISTICS DATA

Suction (in bars)	0.0	0.1	0.33	0.6	1.0	3.0	5.0	15.0
(in cm H_2O)	0	122	403	732	1220	3660	6100	18300
ω %	2.6	2.44	1.79	1.68	1.64	1.38	1.23	1.12
θ %	4.8	4.5	3.3	3.1	3.0	2.5	2.3	2.1
Sr, %	100	93.8	68.8	64.2	63.1	53.1	47.3	43.1
Se,	1.00	0.89	0.45	0.38	0.35	0.18	0.07	0.00

MODEL PARAMETER VALUES

Irreduc. Moist. Content 'θ_r': 0.0021   Vol. Water Capacity '$\theta_s-\theta_r$': 0.0027

Brooks & Corey: PB_d: 73 cm ν_d: 2.5 η: 8.0

Van Genuchten: α: 0.0064 cm^{-1} β: 1.569 γ: 0.363

BASE\SUBBASE #2

SOIL PROPERTIES

TYPE: COARSE AGGREGATE #53 (Type O)

GRAIN SIZE:

% PASSING		
	(1 1/2 in.)	100
	(1 in.)	80-100
	(3/4 in.)	70-90
	(1/2 in.)	55-80
	(#4)	35-60
	(#8)	25-50
	(#30)	12-30
	(#200)	5-10

Density(dry): 143 lb/ft^3

Opt. Moisture: 7.08%

Sp. Gravity: 2.53

Permeability: 3.6×10^{-5} cm/sec (0.12 ft/day)
0.15 cm/sec (499 ft/day) for #53 special subbase gradation

Porosity: 10.8 %

MOISTURE CHARACTERISTICS DATA

Suction (in bars)	0.0	0.1	0.33	0.6	31.0	3.0	5.0	15.0
(in cm H_2O)	0	122	403	732	1220	3660	6100	18300
ω %	7.86	7.19	4.21	3.77	3.3	2.38	1.45	1.37
θ %	10.8	9.9	5.8	5.2	4.6	3.3	2.0	1.9
Sr, %	100	91.5	53.6	47.9	41.9	30.3	18.4	17.4
Se,	1.00	0.89	0.44	0.37	0.30	0.16	0.01	0.00

MODEL PARAMETER VALUES

Irreduc. Moist. Content 'θ_r': 0.019 Vol. Water Capacity '$\theta_s - \theta_r$': 0.089

Brooks & Corey: PB_d: 79 cm v_d: 1.92 η: 6.84

Van Genuchten: α: 0.0052 cm^{-1} β: 1.735 γ: 0.423

BASE/SUBBASE #3

SOIL PROPERTIES

TYPE: COARSE AGGREGATE #73

GRAIN SIZE:

% PASSING	(1 in.)	100
	(3/4 in.)	90-100
	(1/2 in.)	60-90
	(#4)	35-60
	(#30)	12-30
	(#200)	5-10

Density(dry): 132 pcf

Opt. Moisture: 7.1%

Sp. Gravity: 2.72

Permeability: 7.03×10^{-2} cm/sec (192 ft/day)

Porosity: 13.6 %

MOISTURE CHARACTERISTICS DATA

Suction (in bars)	0.0	0.1	0.33	0.6	31.0	3.0	5.0	15.0
(in cm H_2O)	0	122	403	732	1220	3660	6100	18300
ω %	9.9	9.44	7.73	7.31	6.49	3.32	3.17	2.39
θ %	13.6	12.9	10.6	10.0	8.9	4.6	4.3	3.3
Sr, %	100	95.4	78.1	73.8	65.6	33.5	32.0	24.1
Se,	1.00	0.94	0.71	0.66	0.55	0.12	0.10	0.00

MODEL PARAMETER VALUES

Irreduc. Moist. Content 'θ_r': 0.033 Vol. Water Capacity 'θ_s-θ_r': 0.103

Brooks & Corey: PB_d: 85 cm ν_d: 3.15 η: 9.3

Van Genuchten: α: 0.0028 cm^{-1} β: 1.55 γ: 0.355

BASE/SUBBASE #4

SOIL PROPERTIES

TYPE: BITUMINOUS STABILIZED BASE #53B

GRAIN SIZE:

% Passing	(1 1/2 in.)	100
	(1 in.)	90
	(3/4 in.)	80
	(1/2 in.)	68
	(#4)	48
	(#8)	38
	(#30)	21
	(#200)	8

Asphalt Content: 4%

Density: 140 lb/ft^3

Bulk Sp. Gravity: 2.37

Permeability: 2.23×10^{-2} cm/sec (74 ft/day)

Porosity: 5.2 %

MOISTURE CHARACTERISTICS DATA

Suction						
(in bars)	0.0	0.33	1.0	3.0	10.0	15.0
(in cm H_2O)	0	403	1220	3660	12200	18300
ω %	2.28	2.18	2.01	1.98	1.90	1.86
θ %	5.15	4.80	4.54	4.47	4.29	4.20
Sr, %	100	93.2	88.2	86.8	83.3	81.6
Se,	1.0	0.76	0.36	0.28	0.11	0.00

MODEL PARAMETER VALUES

Irreduc. Moist. Content 'θ_r': 0.042 Vol.-Water Capacity 'θ_s-θ_r': 0.0095

Brooks & Corey: PB_d: 122 cm ν_d: 2.3 η: 7.6

Van Genuchten: α: 0.0028 cm^{-1} β: 1.685 γ: 0.4065

BASE/SUBBASE #5

SOIL PROPERTIES

TYPE: Bituminous Stabilized Subbase #5D

GRAIN SIZE:

% PASSING		
	(1 1/2 in.)	100
	(1 in.)	80-99
	(3/4 in.)	68-90
	(1/2 in.)	54-76
	(3/8 in.)	45-67
	(#4)	35-45
	(#8)	20-45
	(#16)	12-36
	(#30)	7-28
	(#100)	1-12
	(#200)	0-4

Asphalt Content: 4.2%

Density (Dry): 144.8 lb/ft ^{3}

Opt. Moisture: 0.5%

Sp. Gravity: 2.33

Permeability: 2.1 x 10^{-4} cm/sec (0.6 ft/day)

Porosity: 3.37 %

MOISTURE CHARACTERISTICS DATA

Suction (in bars)	0.0	0.1	0.33	0.60	1.0	3.0	5.0	15.0
(in cm H_2O)	0	122	403	732	1220	3660	6100	18300
ω %	1.48	1.43	1.38	1.35	1.24	1.21	1.18	1.15
θ %	3.37	3.26	3.15	3.08	2.83	2.76	2.70	2.62
Sr, %	100	96.7	93.5	91.4	83.9	81.9	80.1	77.7
Se,	1.00	0.85	0.71	0.61	0.28	0.19	0.11	0.00

MODEL PARAMETER VALUES

Irreduc. Moist. Content 'θ_r': 0.0262 Vol. Water Capacity 'θ_s-θ_r': 0.0075

Brooks & Corey: PB_d: 88 cm ν_d: 2.11 η: 7.22

Van Genuchten: α: 0.0028 cm^{-1} β: 1.685 γ: 0.4065

Mean and Standard Deviation Values for Gravimetric Moisture Content

Route, County	Soil Type	Pressure in cm of water 122	403	732	1220	3660	6100	18300
US-31, Hamilton	SM-SC	17.63	13.95	12.67	11.43	8.66	7.12	6.27
		1.6	1.37	1.24	1.17	0.82	0.8	0.72
SR-37, Hamilton	SM-SC	10.91	8.82	7.72	7	4.17	3.77	2.97
		0.02	0.43	0.42	0.28	0.16	0.15	0.29
SR-37, Lawrence	CH	39.62	33.18	31.12	28.84	23.32	22.68	21.22
		4.81	4.26	4.16	4.19	3.48	3.05	4.14
US-41, Sullivan	CL	28.97	23.38	21.12	17.15	15.73	13.92	12.89
		0.75	0.46	0.28	0.26	0.75	0.4	0.74
US-30, Laporte	SP-SM	10.15	8.45	6.66	5.95	4.44	3.99	2.88
		2.4	2.43	1.8	1.52	1.01	0.71	0.37
US-31, St.Joseph	SP	7.71	5.67	5.25	4.62	2.91	2.83	2.74
		0.72	0.56	0.56	0.71	0.41	0.32	0.59
SR-9, Noble	SW	11.61	11.35	8.55	7.54	5.86	5.33	4.54
		2.27	2.12	2.15	1.9	1.52	1.48	1.35
SR-43, Tippecanoe	CL	20.7	16.73	15.08	13.67	11.04	10.18	7.8
		1.12	0.98	0.97	0.95	1.1	0.96	1.14
SR-63, Vermillion	GW	19.29	14.64	13.62	11.92	9.42	8.41	7.82
		0.97	0.65	0.76	0.82	0.41	0.34	0.57
US-36, Hendricks	CL	20.11	16.82	13.45	12.89	9.9	8.52	7.14
		1.4	1.25	1.06	0.72	0.78	0.73	0.76
Base No.1	No.24	2.44	1.79	1.68	1.64	1.38	1.23	1.12
		0.15	0.007	0.02	0.007	0.008	0.008	0.02
Base No.2	No.53	7.19	4.21	3.77	3.3	2.38	1.45	1.37
		0.06	0.5	0.38	0.27	0.03	0.1	0.06
Base No.3	No.73	9.44	7.73	7.31	6.49	3.32	3.17	2.39
		0.16	0.09	0.41	0.32	0.007	0.08	0.007
Base No.4	No.53B	2.28	2.18	*	2.01	1.98	1.9	1.86
		0.2	0.18	*	0.3	0.18	0.2	0.19
Base No.5	No.5D	1.43	1.38	1.35	1.24	1.21	1.18	1.15
		0.54	0.53	0.53	0.42	0.43	0.43	0.43

No. of observations: n=6 for subgrade soils; n=2 for base types

Appendix E
Regression Output and Figures for Parameter Estimation

Measured vs Estimated Soil-Moisture Characteristics

suction	ham31 measurd	ham31 B&C	ham31 VanG	ham37 measurd	ham37 B&C	ham37 VanG	lawrnc37 measurd	lawrnc37 B&C	lawrnc37 VanG
122	0.86	0.759504	0.811019	0.9	0.834014	0.872168	0.87	0.809458	0.871826
403	0.58	0.516569	0.560832	0.67	0.572773	0.64058	0.57	0.528271	0.575155
7732	0.49	0.199187	0.156471	0.54	0.226218	0.179498	0.47	0.183928	0.090549
1220	0.39	0.361368	0.355126	0.46	0.404304	0.412096	0.36	0.355673	0.302798
3660	0.18	0.253536	0.218662	0.14	0.2862	0.252513	0.1	0.240243	0.148466
6100	0.06	0.215018	0.174011	0.09	0.243728	0.200064	0.07	0.200179	0.105945
18300	0	0.150857	0.10629	0	0.172531	0.120894	0	0.135213	0.051125

suction	lprt30 measurd	lprt30 B&C	lprt30 VanG	josh31 measurd	josh31 B&C	josh31 VanG	sullvn41 measurd	sullvn41 B&C	sullvn41 VanG
122	0.96	0.878057	0.938353	0.9	0.826001	0.889996	0.88	0.789339	0.803476
403	0.74	0.554534	0.687697	0.53	0.495689	0.625039	0.57	0.530008	0.541131
7732	0.5	0.178021	0.083141	0.46	0.140257	0.12994	0.45	0.197979	0.138256
1220	0.41	0.362166	0.348782	0.34	0.308767	0.362389	0.25	0.366379	0.331734
3660	0.21	0.237355	0.15045	0.03	0.193078	0.197785	0.15	0.254033	0.197607
6100	0.15	0.195017	0.100398	0.02	0.155212	0.148486	0.06	0.21426	0.154854
18300	0	0.12781	0.041817	0	0.097057	0.079951	0	0.148559	0.091515

suction	noble9 measurd	noble9 B&C	noble9 VanG	tippcn43 measurd	tippcn43 B&C	tippcn43 VanG	vermil63 measurd	vermil63 B&C	vermil63 VanG
122	0.98	0.883241	0.954823	0.84	0.795863	0.761465	0.92	0.833033	0.870851
403	0.74	0.608008	0.728468	0.58	0.534388	0.545871	0.55	0.496605	0.568676
7732	0.58	0.241533	0.077333	0.47	0.199616	0.199387	0.46	0.138231	0.085445
1220	0.43	0.43011	0.364749	0.38	0.369407	0.378138	0.33	0.307441	0.294387
3660	0.19	0.305126	0.147337	0.21	0.256132	0.258749	0.13	0.19108	0.141798
6100	0.11	0.260107	0.094937	0.15	0.216031	0.216577	0.05	0.153171	0.100356
18300	0	0.184523	0.036616	0	0.149787	0.147579	0	0.095199	0.047579

suction	hendrk36 measurd	hendrk36 B&C	hendrk36 VanG	base24 measurd	base24 B&C	base24 VanG	base53 measurd	base53 B&C	base53 VanG
122	0.89	0.827211	0.843349	0.89	0.814301	0.82866	0.89	0.797447	0.853359
403	0.66	0.538202	0.58399	0.45	0.504902	0.541377	0.44	0.427974	0.523442
7732	0.43	0.185968	0.142783	0.38	0.397672	0.402364	0.37	0.313628	0.359827
1220	0.39	0.36133	0.355389	0.35	0.324179	0.305849	0.3	0.240363	0.252927
3660	0.2	0.243376	0.207367	0.18	0.208899	0.1655	0.16	0.135634	0.114431
6100	0.09	0.202524	0.160749	0.07	0.170293	0.123897	0.01	0.103949	0.078731
18300	0	0.136411	0.092744	0	0.109736	0.066333	0	0.058657	0.035146

suction	base73 measurd	base73 B&C	base73 VanG	base53b measurd	base53b B&C	base53b VanG	base5d measurd	base5d B&C	base5d VanG
122	0.94	0.891615	0.940335	1	1	1	0.85	0.856564	0.940242
403	0.71	0.610145	0.755137	0.76	0.594801	0.722356	0.71	0.486199	0.722356
732	0.66	0.50483	0.609085	0.57	0.458853	0.550069	0.61	0.36641	0.550069
1220	0.55	0.429257	0.4842	0.36	0.367466	0.410758	0.28	0.287625	0.410758
3660	0.12	0.302866	0.275276	0.28	0.227915	0.20151	0.19	0.170884	0.20151
6100	0.1	0.257527	0.208901	0.22	0.182523	0.142669	0.11	0.134141	0.142669
18300	0	0.1817	0.114536	0	0.113207	0.067417	0	0.079696	0.067417

Measured vs Estimated Soil-Moisture Characteristics

Regression Analysis For Base #24

Brooks & Corey Regression Output			Van Genuchten Regression Output		
Constant		0	Constant		0
Std Err of Y Est		0.053472	Std Err of Y Est		0.059796
R Squared		0.965107	R Squared		0.961388
No. of Observations		7	No. of Observations		7
Degrees of Freedom		6	Degrees of Freedom		6
X Coefficient(s)	0.99698		X Coefficient(s)	1.051916	
Std Err of Coef.	0.048052		Std Err of Coef.	0.053736	

Regression Analysis For Base #53

Brooks & Corey Regression Output			Van Genuchten Regression Output		
Constant		0	Constant		0
Std Err of Y Est		0.074983	Std Err of Y Est		0.066116
R Squared		0.919174	R Squared		0.944211
No. of Observations		7	No. of Observations		7
Degrees of Freedom		6	Degrees of Freedom		6
X Coefficient(s)	1.057428		X Coefficient(s)	1.049181	
Std Err of Coef.	0.065795		Std Err of Coef.	0.058014	

Regression Analysis For Base #73

Brooks & Corey Regression Output			Van Genuchten Regression Output		
Constant		0	Constant		0
Std Err of Y Est		0.149321	Std Err of Y Est		0.111032
R Squared		0.669958	R Squared		0.867406
No. of Observations		7	No. of Observations		7
Degrees of Freedom		6	Degrees of Freedom		6
X Coefficient(s)	0.940962		X Coefficient(s)	1.041759	
Std Err of Coef.	0.101832		Std Err of Coef.	0.075719	

Regression Analysis For Base #53B

Brooks & Corey Regression Output			Van Genuchten Regression Output		
Constant		0	Constant		0
Std Err of Y Est		0.073936	Std Err of Y Est		0.063138
R Squared		0.940141	R Squared		0.965001
No. of Observations		7	No. of Observations		7
Degrees of Freedom		6	Degrees of Freedom		6
X Coefficient(s)	0.935289		X Coefficient(s)	1.012422	
Std Err of Coef.	0.05032		Std Err of Coef.	0.042971	

Regression Analysis For Base #5D

Brooks & Corey Regression Output			Van Genuchten Regression Output		
Constant		0	Constant		0
Std Err of Y Est		0.122469	Std Err of Y Est		0.083827
R Squared		0.829899	R Squared		0.934177
No. of Observations		7	No. of Observations		7
Degrees of Freedom		6	Degrees of Freedom		6
X Coefficient(s)	0.905366		X Coefficient(s)	1.106527	
Std Err of Coef.	0.093238		Std Err of Coef.	0.063819	

Measured vs Estimated Soil-Moisture Characteristics

Regression Analysis for SP-Soil (US-31, St.Joseph County)

Brooks & Corey Regression Output			Van Genuchten Regression Output		
Constant		0	Constant		0
Std Err of Y Est		0.107916	Std Err of Y Est		0.114383
R Squared		0.845961	R Squared		0.851323
No. of Observations		7	No. of Observations		7
Degrees of Freedom		6	Degrees of Freedom		6
X Coefficient(s)	0.994909		X Coefficient(s)	1.039939	
Std Err of Coef.	0.09058		Std Err of Coef.	0.096009	

Regression Analysis for SM-SC Soil (US-31, Hamilton County)

Brooks & Corey Regression Output			Van Genuchten Regression Output		
Constant		0	Constant		0
Std Err of Y Est		0.054318	Std Err of Y Est		0.075897
R Squared		0.929678	R Squared		0.911972
No. of Observations		5	No. of Observations		7
Degrees of Freedom		4	Degrees of Freedom		6
X Coefficient(s)	0.957485		X Coefficient(s)	1.004577	
Std Err of Coef.	0.044342		Std Err of Coef.	0.061883	

Regression Analysis for SM-SC Soil (SR-37, Hamilton County)

Brooks & Corey Regression Output			Van Genuchten Regression Output		
Constant		0	Constant		0
Std Err of Y Est		0.12714	Std Err of Y Est		0.09445
R Squared		0.723978	R Squared		0.879563
No. of Observations		7	No. of Observations		7
Degrees of Freedom		6	Degrees of Freedom		6
X Coefficient(s)	0.973431		X Coefficient(s)	1.017807	
Std Err of Coef.	0.095034		Std Err of Coef.	0.070599	

Regression Analysis for CH Soil (SR-37, Lawrence County)

Brooks & Corey Regression Output			Van Genuchten Regression Output		
Constant		0	Constant		0
Std Err of Y Est		0.107274	Std Err of Y Est		0.047179
R Squared		0.815068	R Squared		0.975803
No. of Observations		7	No. of Observations		7
Degrees of Freedom		6	Degrees of Freedom		6
X Coefficient(s)	1.017196		X Coefficient(s)	1.038063	
Std Err of Coef.	0.089172		Std Err of Coef.	0.039218	

Regression Analysis for SP-SM Soil (US-30, Laporte County)

Brooks & Corey Regression Output			Van Genuchten Regression Output		
Constant		0	Constant		0
Std Err of Y Est		0.084914	Std Err of Y Est		0.031992
R Squared		0.907808	R Squared		0.991057
No. of Observations		7	No. of Observations		7
Degrees of Freedom		6	Degrees of Freedom		6
X Coefficient(s)	0.939057		X Coefficient(s)	1.000122	
Std Err of Coef.	0.060748		Std Err of Coef.	0.022837	

Measured vs Estimated Soil-Moisture Characteristics

Regression Analysis for CL Soil (US-41, Sullivan County)

Brooks & Corey Regression Output			Van Genuchten Regression Output		
Constant		0	Constant		0
Std Err of Y Est		0.122624	Std Err of Y Est		0.083921
R Squared		0.729074	R Squared		0.895427
No. of Observations		7	No. of Observations		7
Degrees of Freedom		6	Degrees of Freedom		6
X Coefficient(s)	1.025082		X Coefficient(s)	1.010887	
Std Err of Coef.	0.103993		Std Err of Coef.	0.071171	

Regression Analysis for SW Soil (Noble County)

Brooks & Corey Regression Output			Van Genuchten Regression Output		
Constant		0	Constant		0
Std Err of Y Est		0.127734	Std Err of Y Est		0.022466
R Squared		0.750042	R Squared		0.995912
No. of Observations		7	No. of Observations		7
Degrees of Freedom		6	Degrees of Freedom		6
X Coefficient(s)	0.961473		X Coefficient(s)	1.004715	
Std Err of Coef.	0.088621		Std Err of Coef.	0.015586	

Regression Analysis for CL Soil (SR-43, Tippecanoe County)

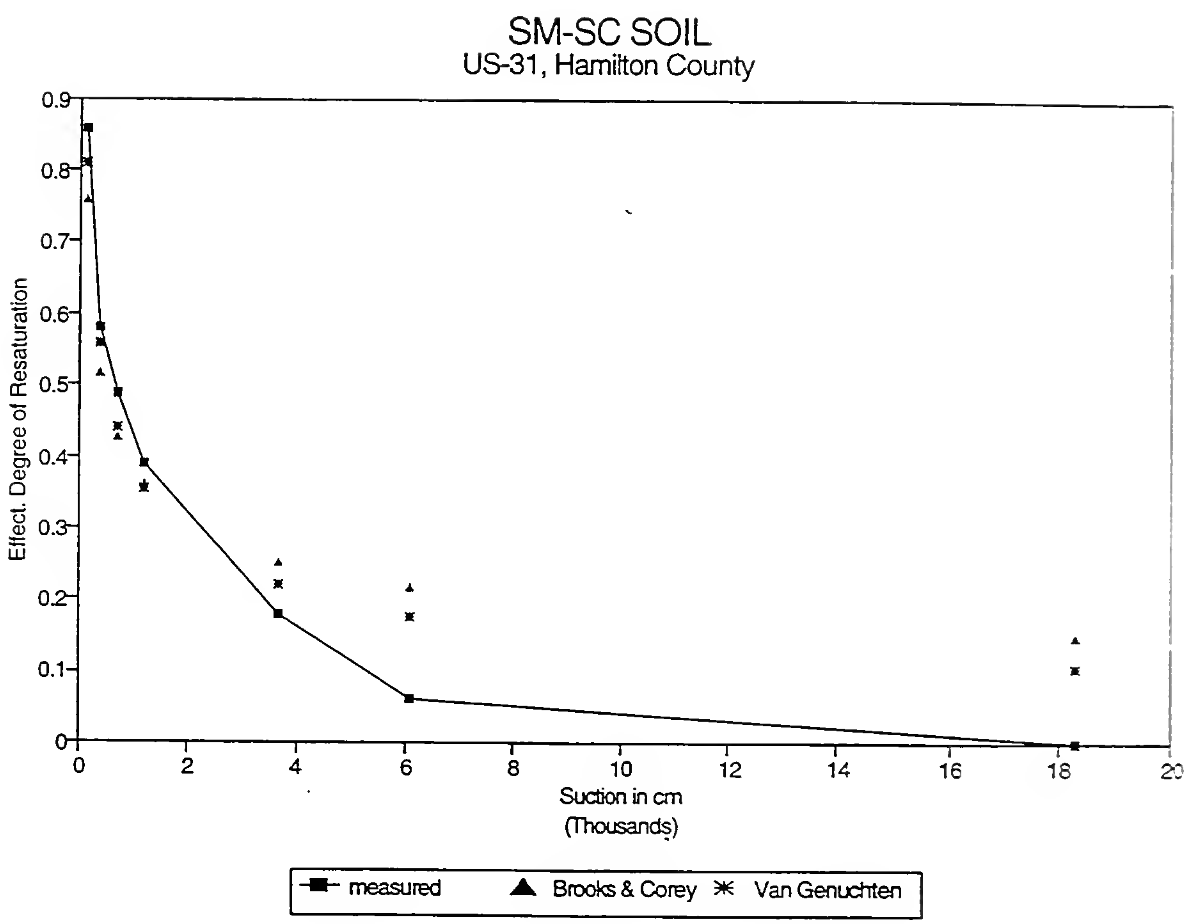
Brooks & Corey Regression Output			Van Genuchten Regression Output		
Constant		0	Constant		0
Std Err of Y Est		0.078693	Std Err of Y Est		0.080947
R Squared		0.890243	R Squared		0.865933
No. of Observations		7	No. of Observations		7
Degrees of Freedom		6	Degrees of Freedom		6
X Coefficient(s)	1.022122		X Coefficient(s)	0.99955	
Std Err of Coef.	0.064819		Std Err of Coef.	0.066676	

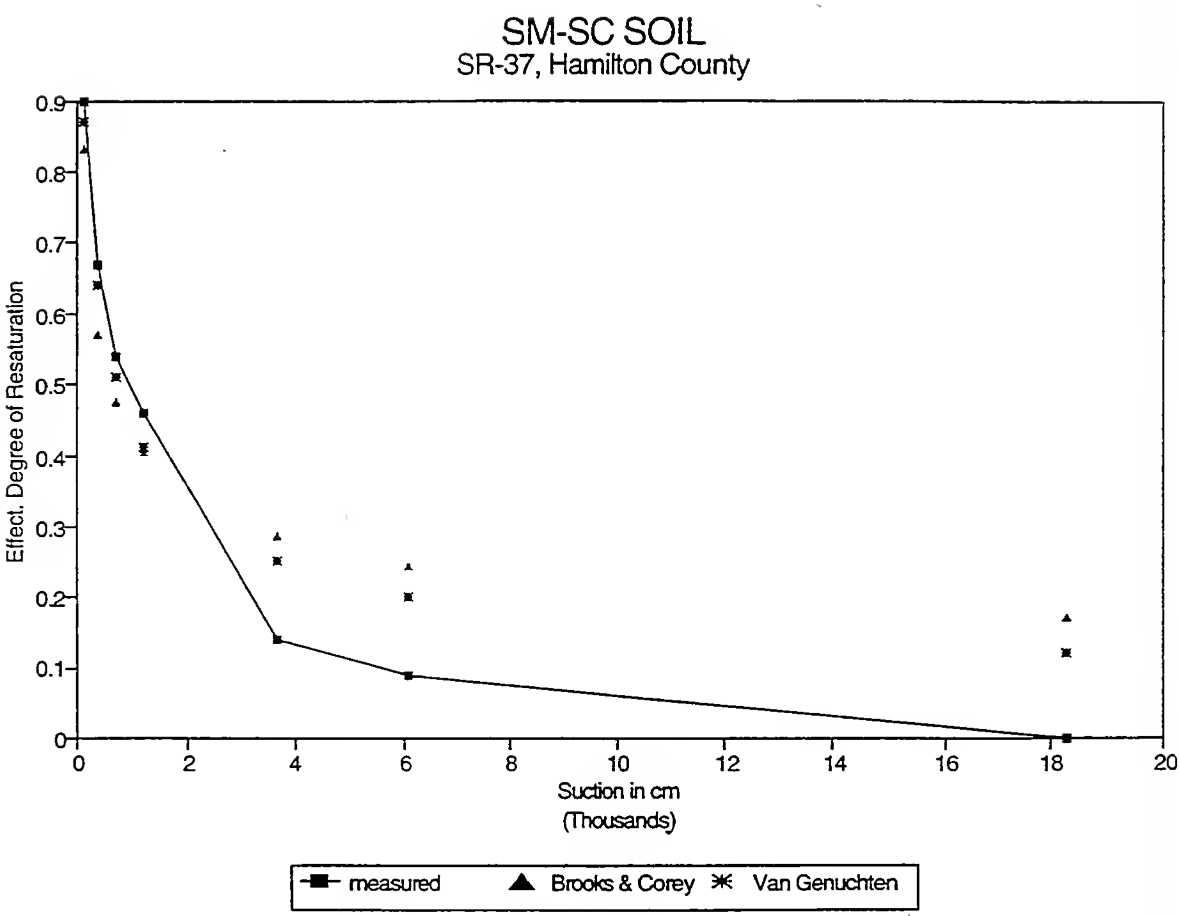
Regression Analysis for GW Soil (SR-63, Vermillion County)

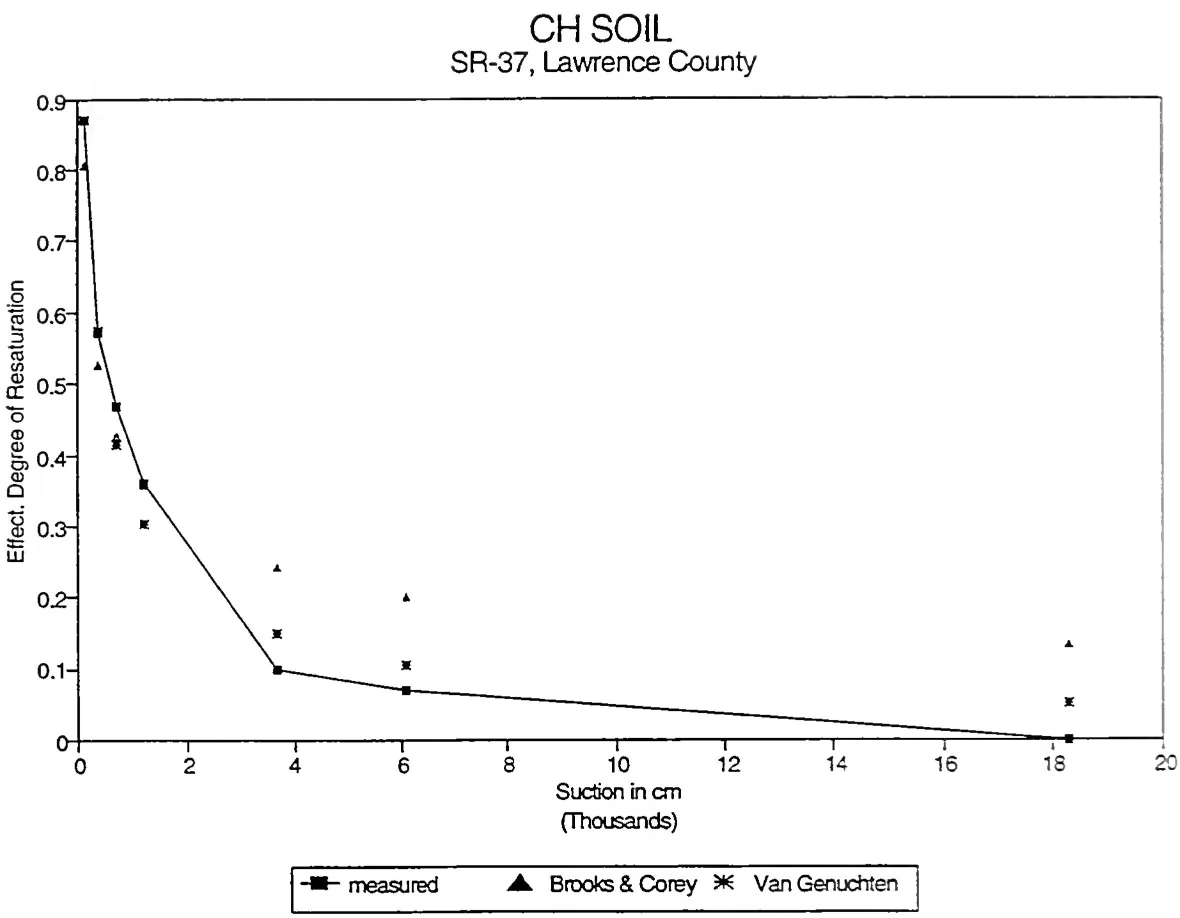
Brooks & Corey Regression Output			Van Genuchten Regression Output		
Constant		0	Constant		0
Std Err of Y Est		0.075233	Std Err of Y Est		0.045025
R Squared		0.927156	R Squared		0.978158
No. of Observations		7	No. of Observations		7
Degrees of Freedom		6	Degrees of Freedom		6
X Coefficient(s)	0.988881		X Coefficient(s)	1.015568	
Std Err of Coef.	0.061658		Std Err of Coef.	0.036901	

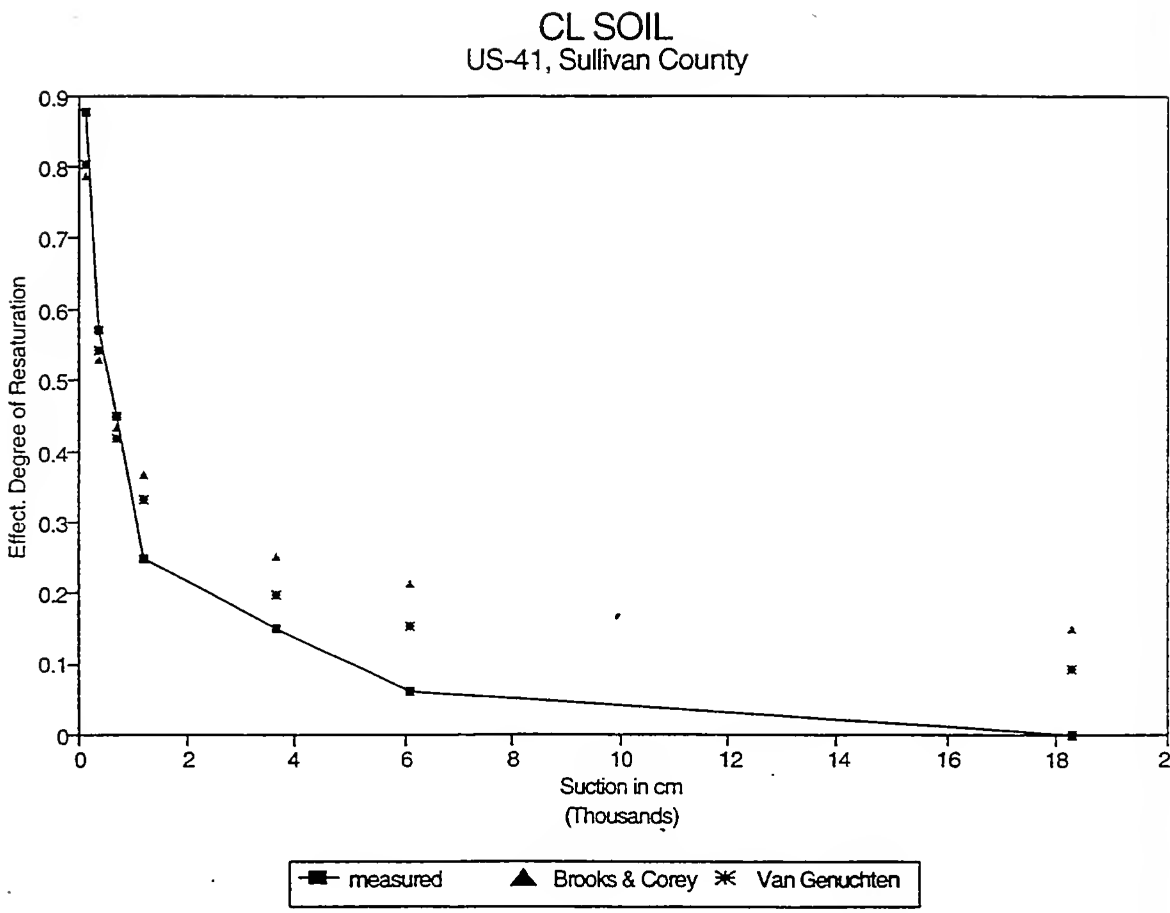
Regression Analysis for CL Soil (US-36, Hendricks County)

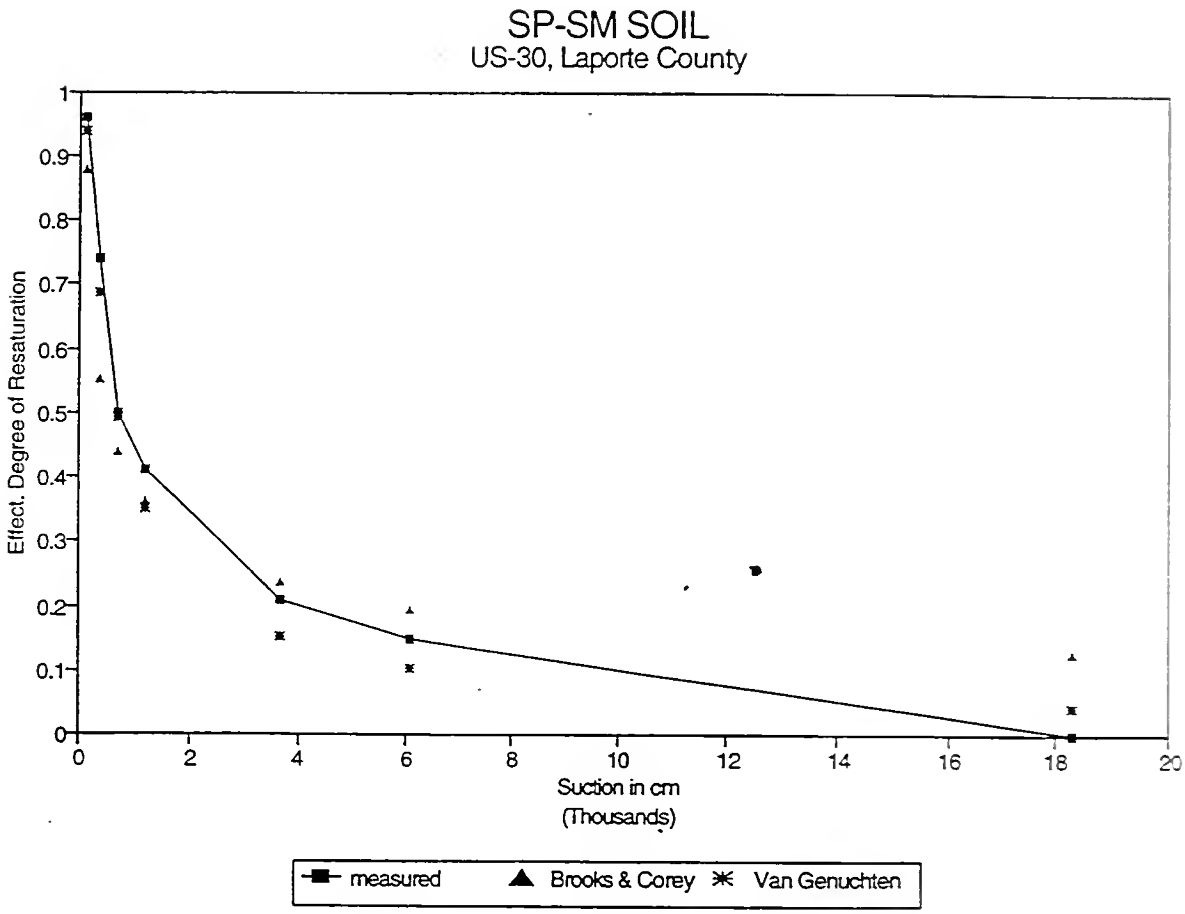
Brooks & Corey Regression Output			Van Genuchten Regression Output		
Constant		0	Constant		0
Std Err of Y Est		0.092131	Std Err of Y Est		0.062525
R Squared		0.870245	R Squared		0.947696
No. of Observations		7	No. of Observations		7
Degrees of Freedom		6	Degrees of Freedom		6
X Coefficient(s)	0.989204		X Coefficient(s)	1.000653	
Std Err of Coef.	0.072547		Std Err of Coef.	0.049234	


SM-SC SOIL
US-31, Hamilton County
Effect. Degree of Resaturation
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
16
18
20
Suction in cm
(Thousands)
measured
Brooks & Corey
Van Genuchten

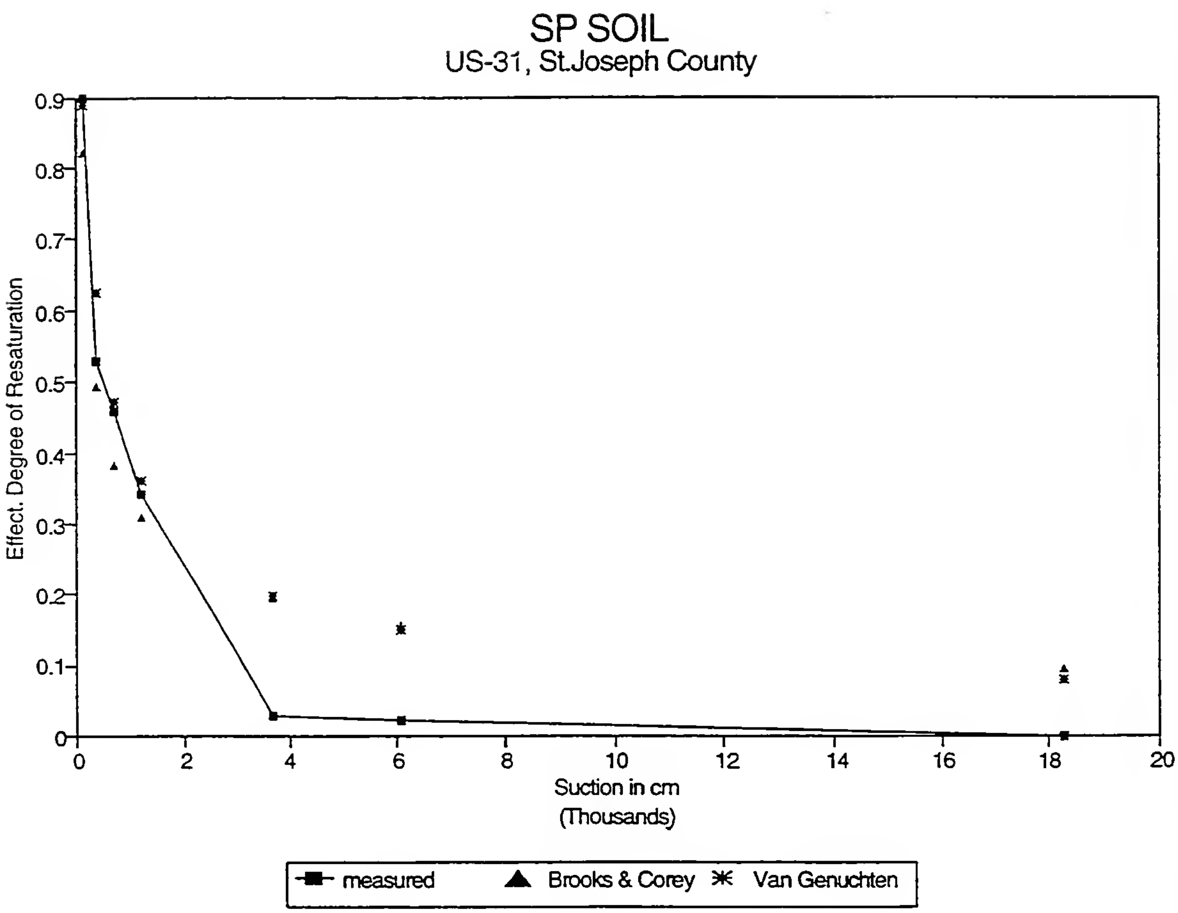

SM-SC SOIL
SR-37, Hamilton County
Effect. Degree of Resaturation
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0
2
4
6
8
10
12
14
16
18
20
Suction in cm
(Thousands)
measured
Brooks & Corey
Van Genuchten

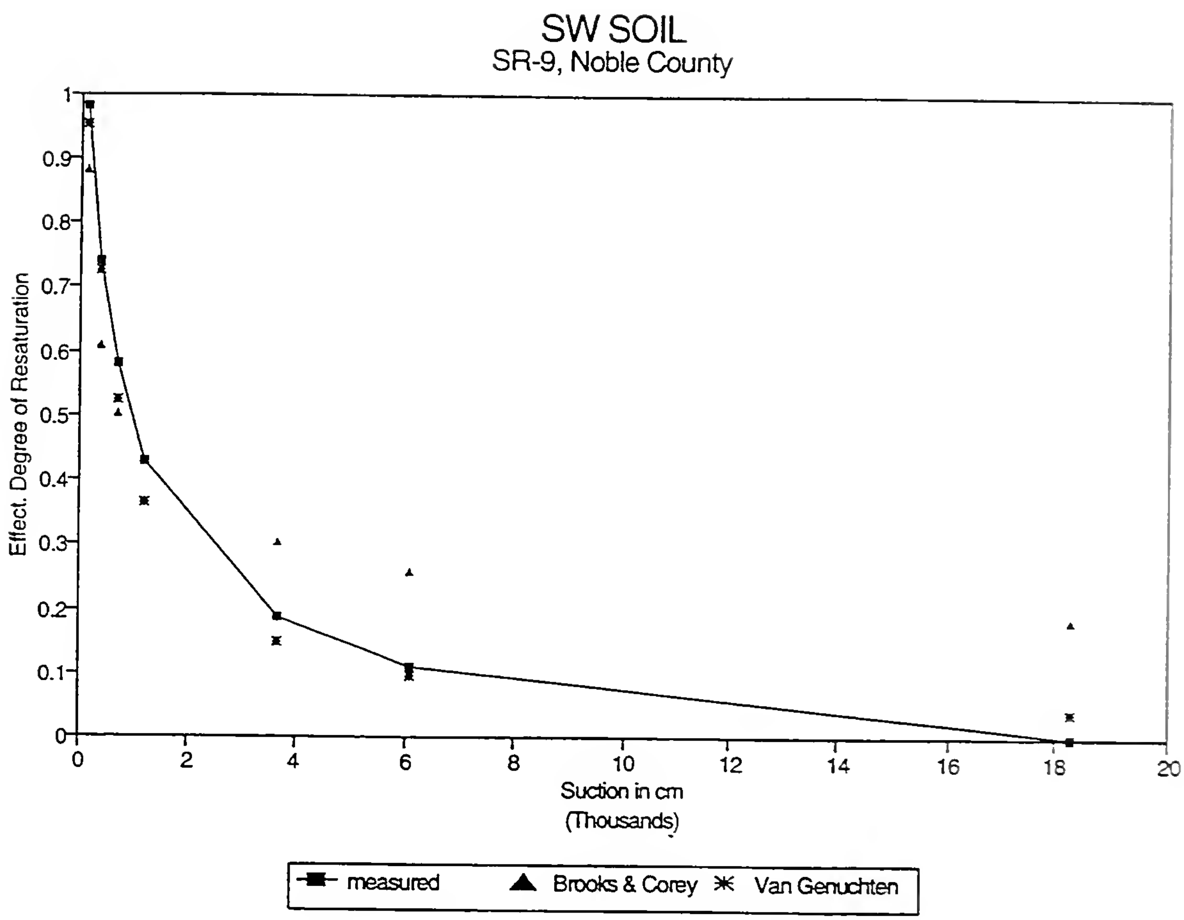

CH SOIL
SR-37, Lawrence County
Effect. Degree of Resaturation
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0
2
4
6
8
10
12
14
16
18
20
Suction in cm
(Thousands)
measured
Brooks & Corey
Van Genuchten

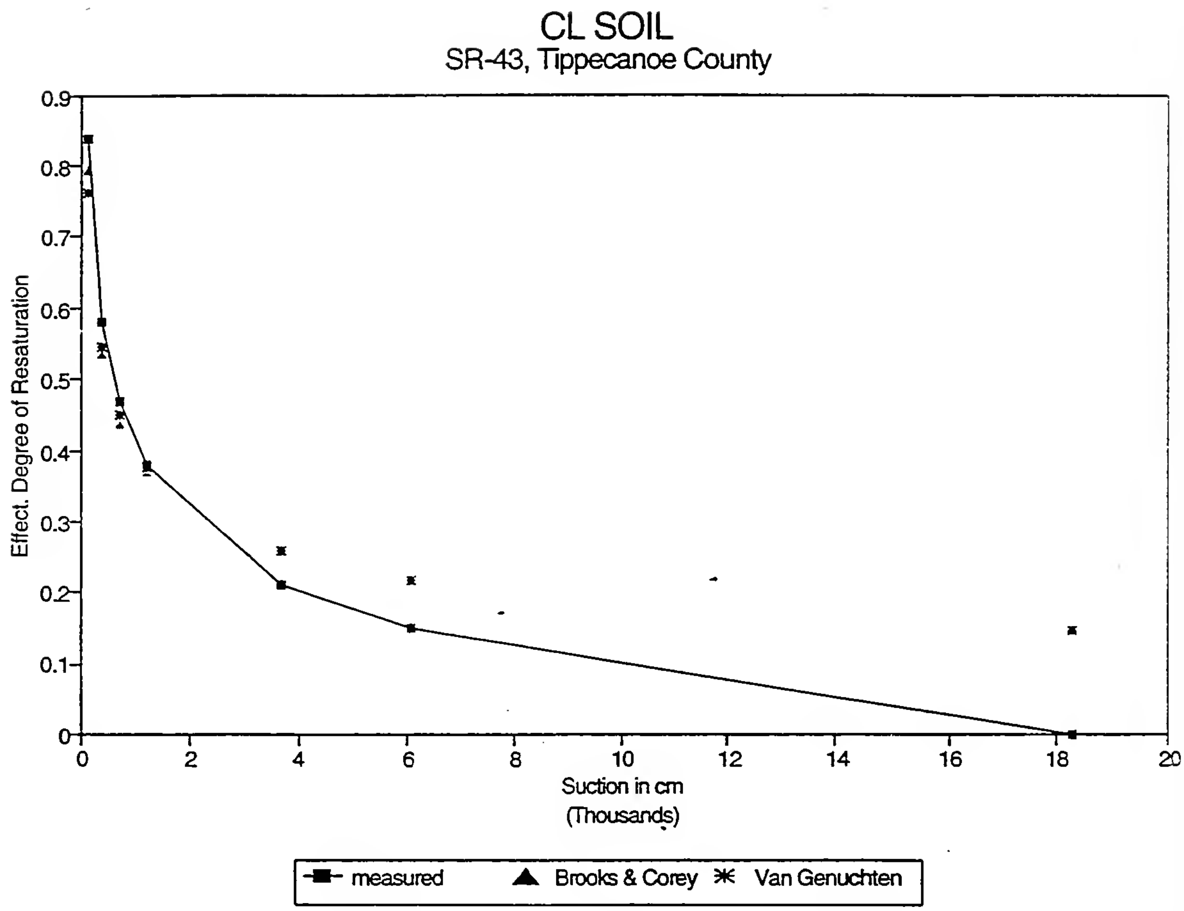

CL SOIL
US-41, Sullivan County
Effect. Degree of Resaturation
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2
4
6
8
10
12
14
16
18
20
Suction in cm
(Thousands)
measured
Brooks & Corey
Van Genuchten

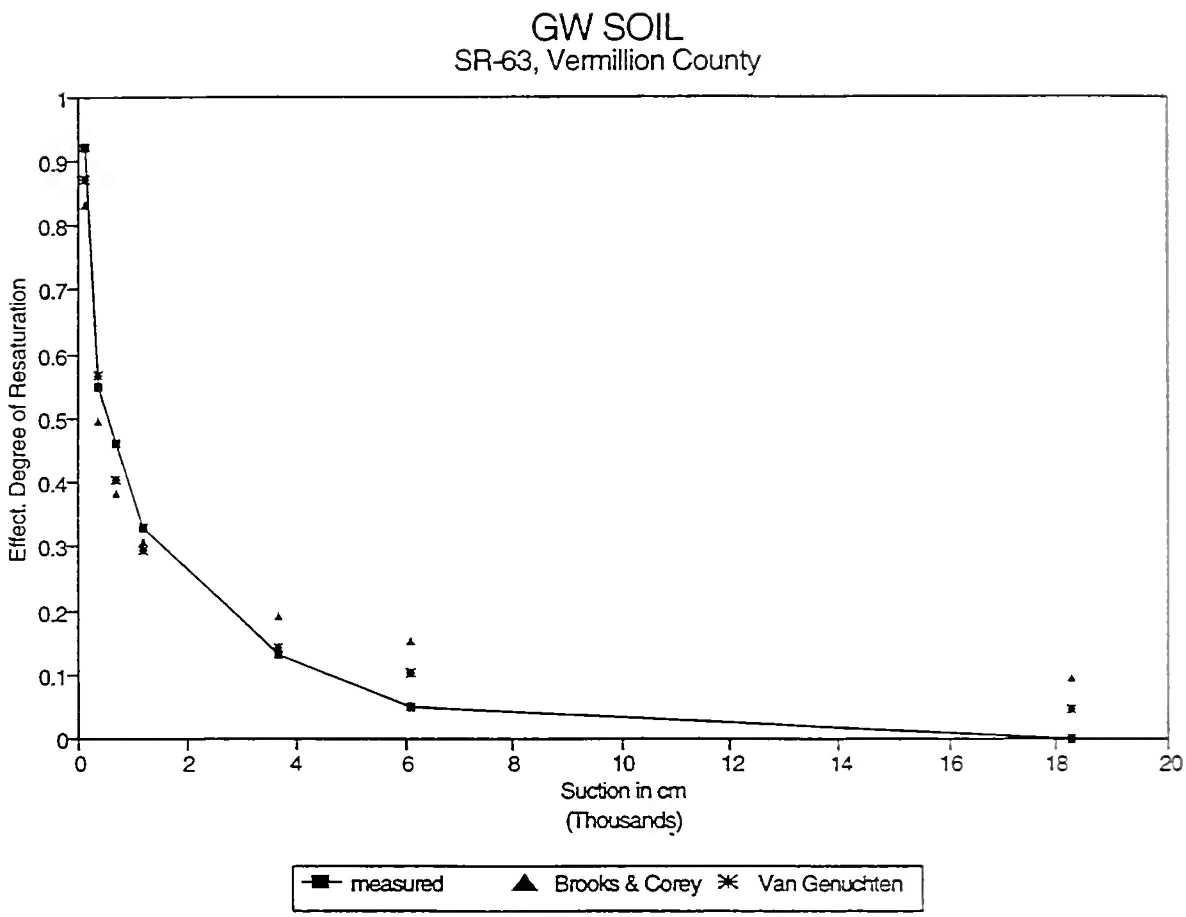


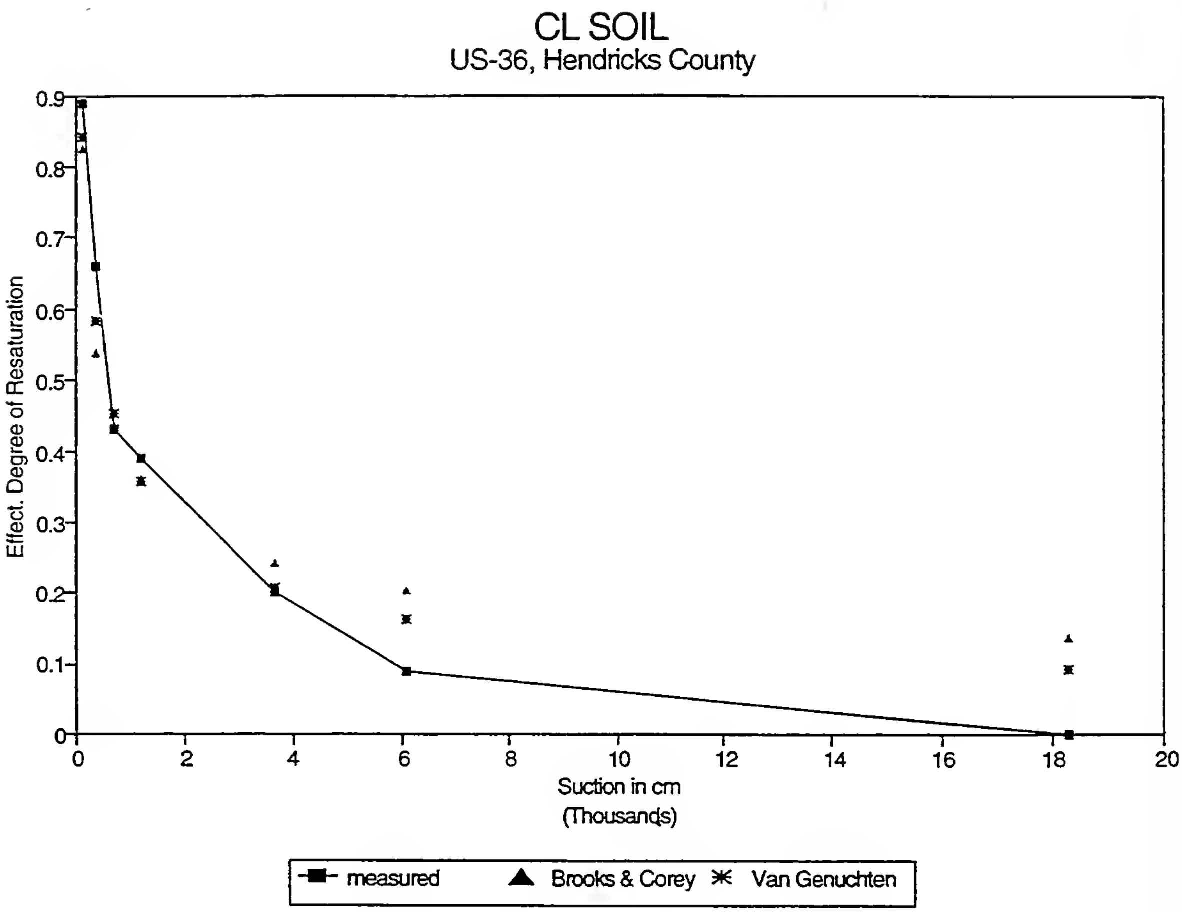
SP-SM SOIL
US-30, Laporte County
Effect. Degree of Resaturation
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
2
4
6
8
10
12
14
16
18
20
Suction in cm
(Thousands)
measured
Brooks & Corey
Van Genuchten

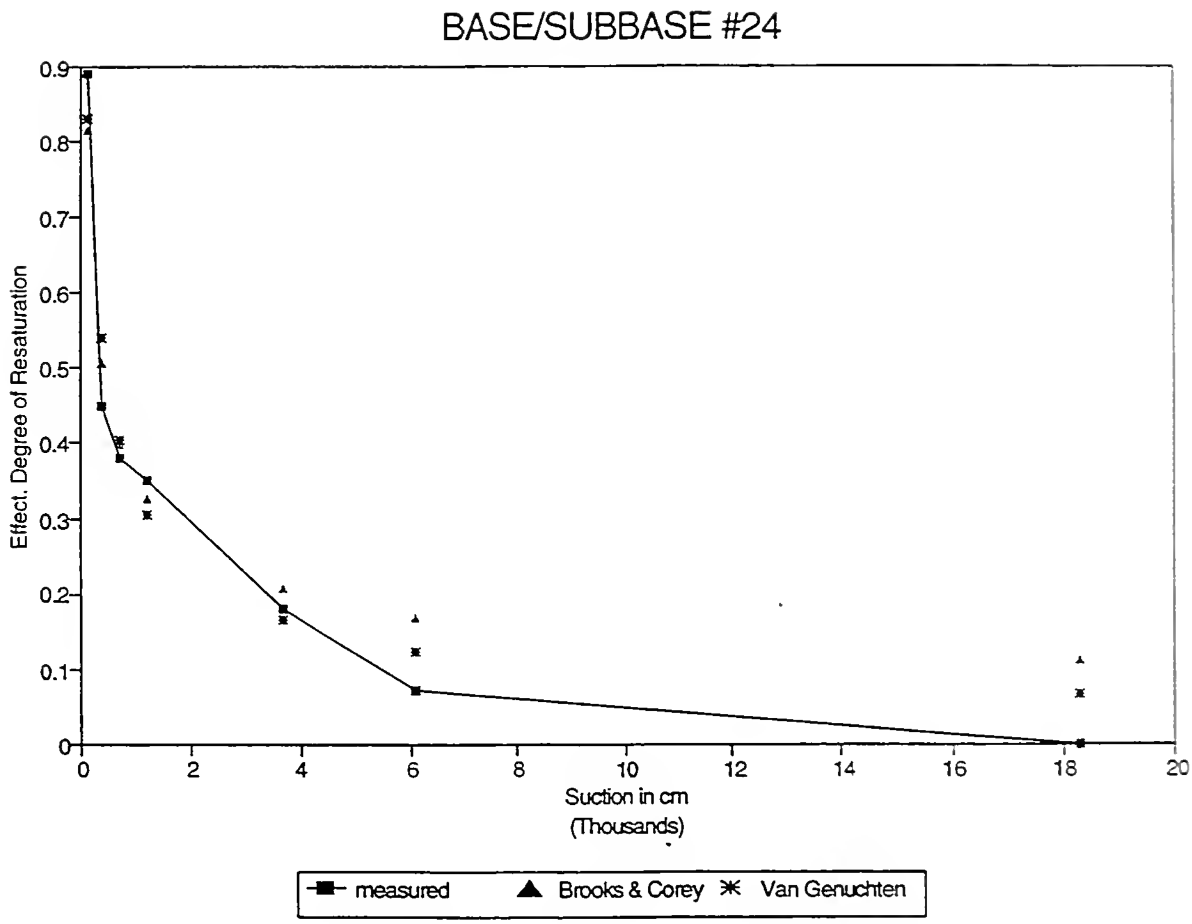

SP SOIL
US-31, St.Joseph County
Effect. Degree of Resaturation
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0
2
4
6
8
10
12
14
16
18
20
Suction in cm
(Thousands)
measured
Brooks & Corey
Van Genuchten

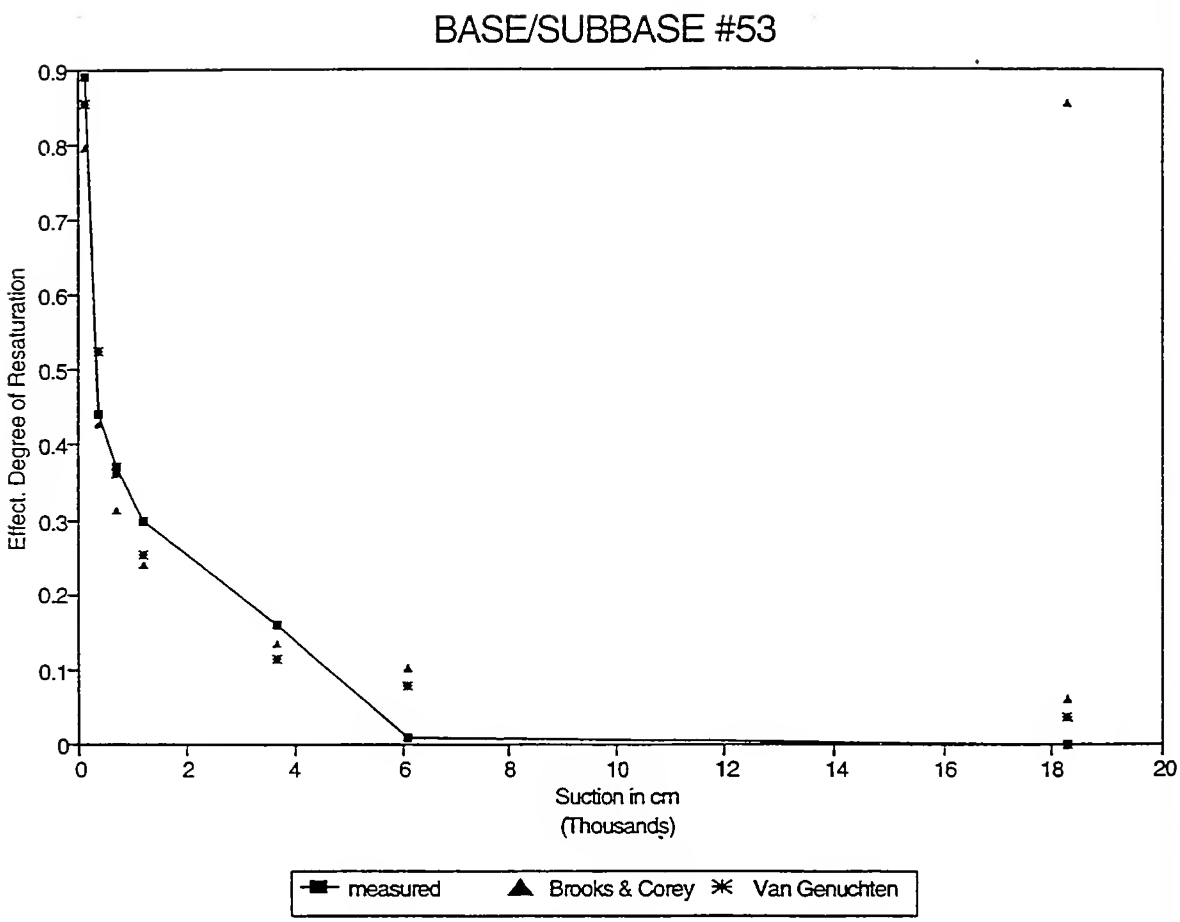

SW SOIL
SR-9, Noble County
Effect. Degree of Resaturation
Suction in cm
(Thousands)
measured
Brooks & Corey
Van Genuchten
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2
4
6
8
10
12
14
16
18
20

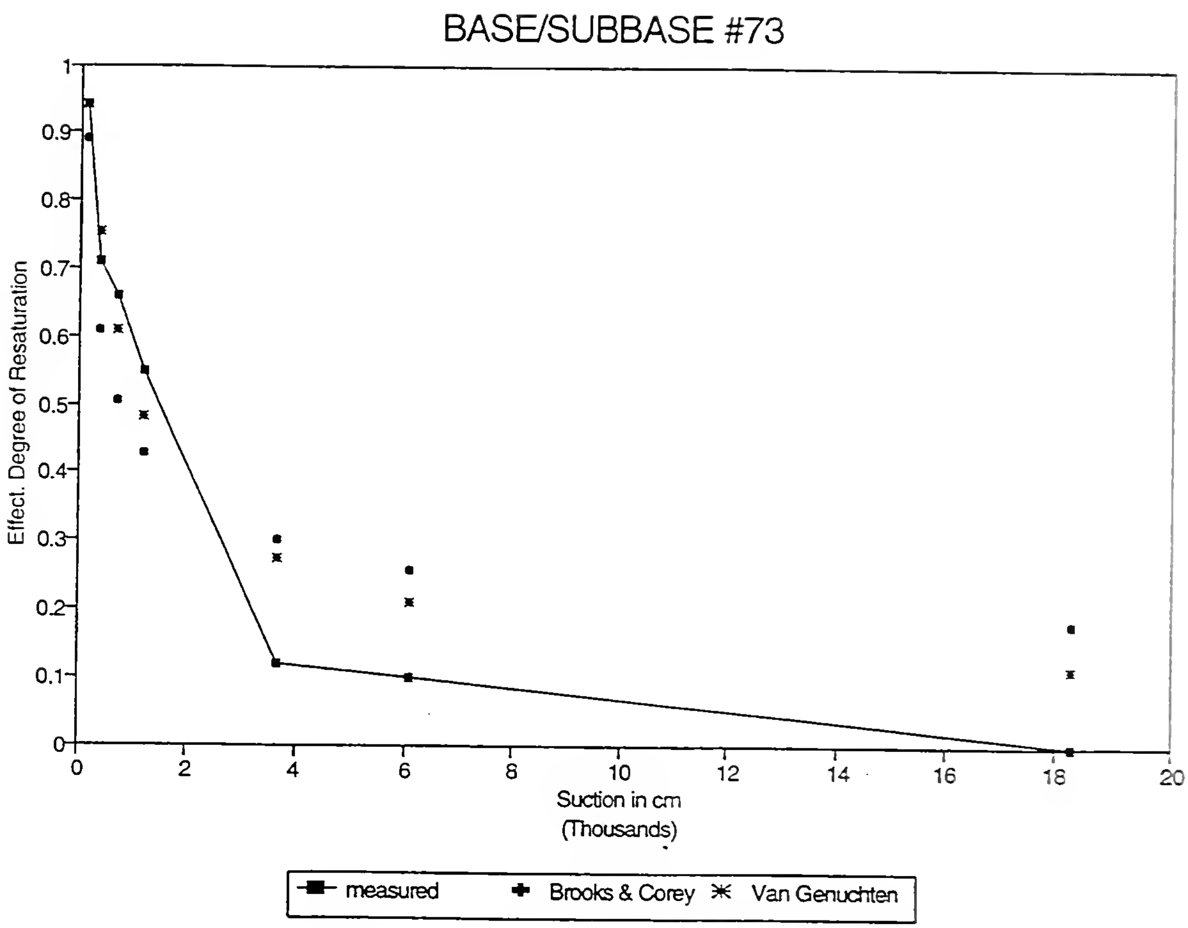

CL SOIL
SR-43, Tippecanoe County
Effect. Degree of Resaturation
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
16
18
20
Suction in cm
(Thousands)
measured
Brooks & Corey
Van Genuchten

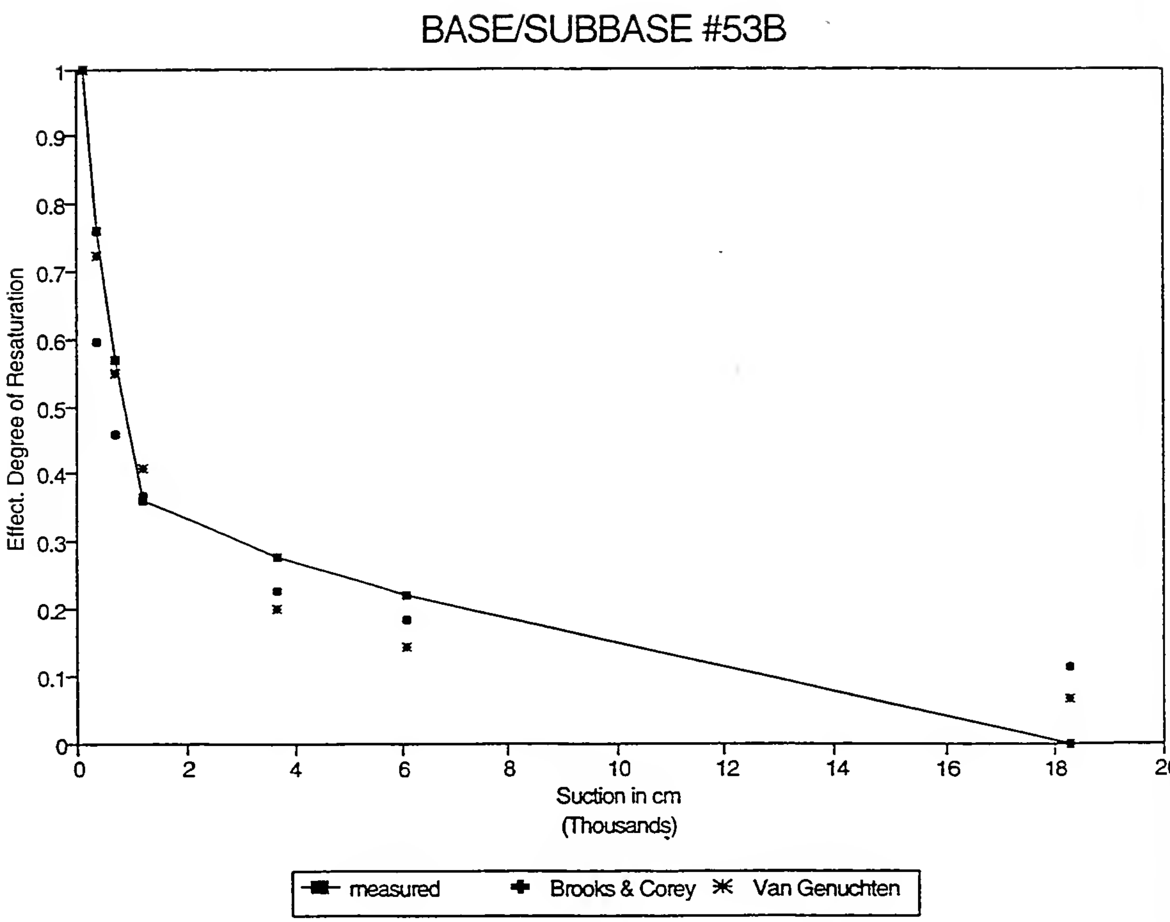

GW SOIL
SR-63, Vermillion County
Effect. Degree of Resaturation
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
16
18
20
Suction in cm
(Thousands)
measured
Brooks & Corey
Van Genuchten

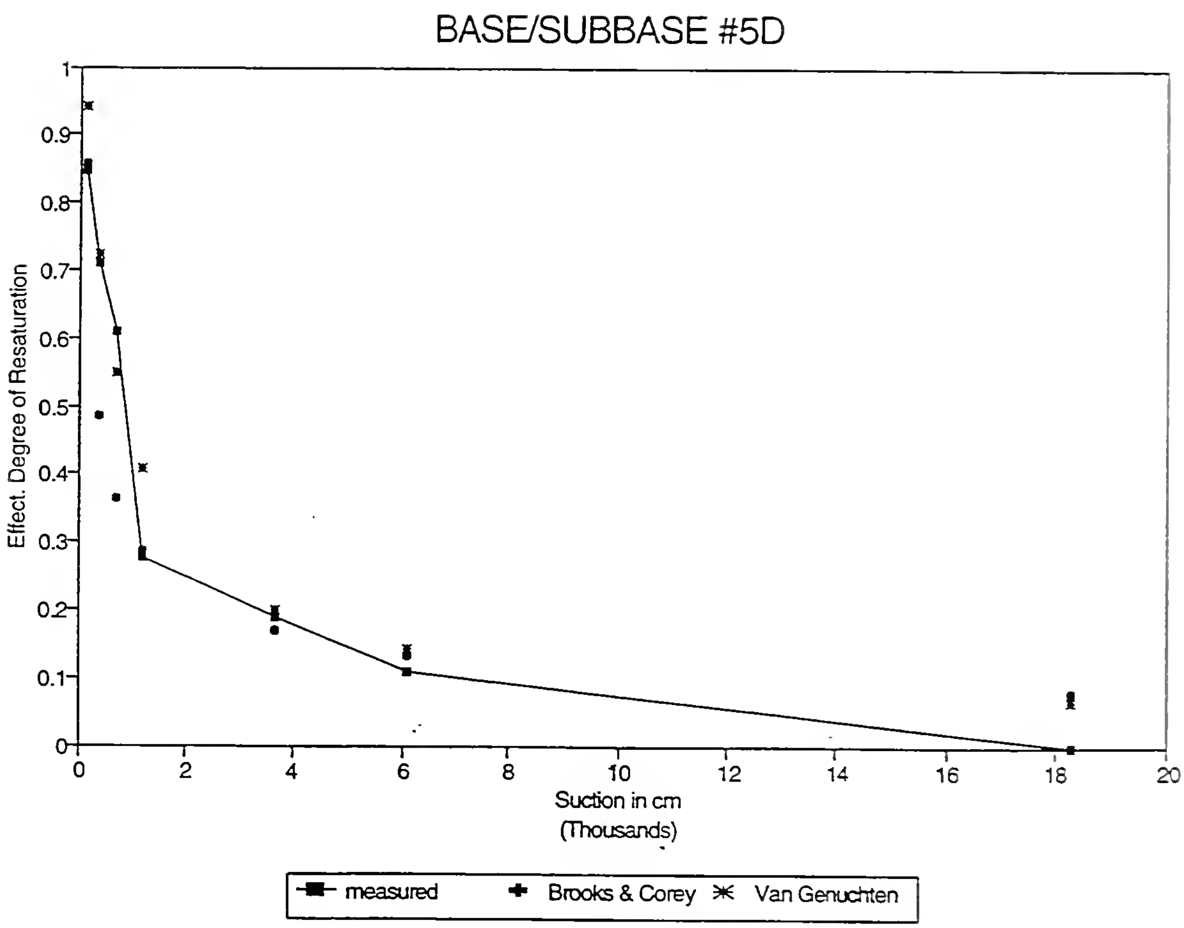

CL SOIL
US-36, Hendricks County
Effect. Degree of Resaturation
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
16
18
20
Suction in cm
(Thousands)
measured
Brooks & Corey
Van Genuchten


BASE/SUBBASE #24
Effect. Degree of Resaturation
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
16
18
20
Suction in cm
(Thousands)
measured
Brooks & Corey
Van Genuchten


BASE/SUBBASE #53
Effect. Degree of Resaturation
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
16
18
20
Suction in cm
(Thousands)
measured
Brooks & Corey
Van Genuchten


BASE/SUBBASE #73
Effect. Degree of Resaturation
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
16
18
20
Suction in cm
(Thousands)
measured
Brooks & Corey
Van Genuchten


BASE/SUBBASE #53B
Effect. Degree of Resaturation
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
16
18
20
Suction in cm
(Thousands)
measured
Brooks & Corey
Van Genuchten


BASE/SUBBASE #5D
Effect. Degree of Resaturation
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
2
4
6
8
10
12
14
16
18
20
Suction in cm
(Thousands)
measured
Brooks & Corey
Van Genuchten

Appendix F
Data From Instrumented Sites

US-31, Hamilton County (DATA SET 1 for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	3129	325	2400	0.04	48.3332	48.3332	0	0	0
2	3129	326	100	0.07	84.5831	132.9163	0	0	0
3	3129	326	200	0.11	132.9163	265.8326	0	0	0
4	3129	326	300	0.06	72.4998	338.3324	0	0	0
5	3129	326	400	0.03	36.2499	374.5823	0	0	0
6	3129	326	500	0.11	132.9163	507.4986	0	0	0
7	3129	326	600	0.06	72.4998	579.9984	0	0	0
8	3129	326	700	0.03	36.2499	616.2483	0	0	0
9	3129	326	800	0.02	24.1666	640.4149	0	0	0
10	3129	326	900	0.02	24.1666	664.5815	0	0	0
11	3129	326	1000	0	0	664.5815	0	0	0
12	3129	326	1100	0	0	664.5815	0	0	0
13	3129	326	1200	0	0	664.5815	0	0	0
14	3129	326	1300	0	0	664.5815	0	0	0
15	3129	326	1400	0	0	664.5815	0	0	0
16	3129	326	1500	0	0	664.5815	0	0	0
17	3129	326	1600	0	0	664.5815	0	0	0
18	3129	326	1700	0	0	664.5815	0	0	0
19	3129	326	1800	0	0	664.5815	0	0	0
20	3129	326	1900	0	0	664.5815	0	0	0
21	3129	326	2000	0	0	664.5815	0	0	0
22	3129	326	2100	0	0	664.5815	0	0	0
23	3129	326	2200	0	0	664.5815	0	0	0
24	3129	326	2300	0	0	664.5815	0	0	0
25	3129	326	2400	0	0	664.5815	0	0	0
26	3129	327	100	0	0	664.5815	0	0	0
27	3129	327	200	0	0	664.5815	0	0	0
28	3129	327	300	0	0	664.5815	0	0	0
29	3129	327	400	0	0	664.5815	0	0	0
30	3129	327	500	0	0	664.5815	0	0	0
31	3129	327	600	0	0	664.5815	0	0	0
32	3129	327	700	0	0	664.5815	0	0	0
33	3129	327	800	0	0	664.5815	0	0	0
34	3129	327	1500	0	0	664.5815	0.00447	0.035877	0.035877
35	3129	327	1600	0	0	664.5815	0.38469	3.087599	3.123476
36	3129	327	1700	0	0	664.5815	0.33549	2.69271	5.816186
37	3129	327	1800	0	0	664.5815	0.30418	2.44141	8.257595
38	3129	327	1900	0	0	664.5815	0.27734	2.225986	10.48358
39	3129	327	2000	0	0	664.5815	0.25497	2.04644	12.53002
40	3129	327	2100	0	0	664.5815	0.20577	1.651551	14.18157
41	3129	327	2200	0	0	664.5815	0.20129	1.615594	15.79717
42	3129	327	2300	0	0	664.5815	0.19682	1.579717	17.37688
43	3129	327	2400	0	0	664.5815	0.18787	1.507882	18.88477
44	3129	328	100	0	0	664.5815	0.17445	1.400171	20.28494
45	3129	328	200	0	0	664.5815	0.16551	1.328416	21.61335
46	3129	328	300	0	0	664.5815	0.14761	1.184747	22.7981
47	3129	328	400	0	0	664.5815	0.13419	1.077036	23.87514
48	3129	328	500	0	0	664.5815	0.13419	1.077036	24.95217
49	3129	328	600	0	0	664.5815	0.13419	1.077036	26.02921
50	3129	328	700	0	0	664.5815	0.12078	0.969404	26.99861
51	3129	328	800	0	0	664.5815	0.1163	0.933447	27.93206
52	3129	328	900	0	0	664.5815	0.10736	0.861693	28.79375
53	3129	328	1000	0	0	664.5815	0.10288	0.825735	29.61949
54	3129	328	1100	0	0	664.5815	0.09841	0.789858	30.40935
55	3129	328	1200	0	0	664.5815	0.09841	0.789858	31.1992
56	3129	328	1300	0	0	664.5815	0.09841	0.789858	31.98906
57	3129	328	1400	0	0	664.5815	0.10288	0.825735	32.8148
58	3129	328	1500	0	0	664.5815	0.09841	0.789858	33.60466
59	3129	328	1600	0	0	664.5815	0.09394	0.753981	34.35864
60	3129	328	1700	0	0	664.5815	0.08946	0.718024	35.07666
61	3129	328	1800	0	0	664.5815	0.05368	0.430846	35.50751
62	3129	328	1900	0	0	664.5815	0.0492	0.394889	35.9024
63	3129	328	2000	0	0	664.5815	0.0492	0.394889	36.29729
64	3129	328	2100	0	0	664.5815	0.04473	0.359012	36.6563
65	3129	328	2200	0	0	664.5815	0.01789	0.143589	36.79989
66	3129	328	2300	0	0	664.5815	0	0	36.79989
			CUMUL	0.55	664.5815		4.58497	36.79989	
			VOLUME IN CFT	664.5833			36.79989		
			Outflow vol. as percentage of precip. volume				5.537287		

US-31, Hamilton County (DATA SET 2 for Rain and Flow)

TOT.HRS	RTE/CNT	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	3129	331	100	0.01	12.0833	12.0833	0	0	0
2	3129	331	200	0.41	495.4153	507.4986	0.42048	3.374857	3.374857
3	3129	331	300	0	0	507.4986	1.8832	15.11494	18.4898
4	3129	331	400	0.1	120.833	628.3316	2.3797	19.09955	37.58974
5	3129	331	500	0.22	265.8326	894.1642	4.2316	33.96367	71.55341
6	3129	331	600	0.12	144.9996	1039.1638	4.4776	35.93811	107.4915
7	3129	331	700	0.08	96.6664	1135.8302	4.5045	36.15402	143.6455
8	3129	331	800	0.05	60.4165	1196.2467	4.4911	36.04647	179.692
9	3129	331	900	0	0	1196.2467	3.9453	31.66577	211.3578
10	3129	331	1000	0.15	181.2495	1377.4962	3.7932	30.44498	241.8028
11	3129	331	1100	0.04	48.3332	1425.8294	4.4553	35.75913	277.5619
12	3129	331	1200	0.04	48.3332	1474.1626	4.008	32.16901	309.7309
13	3129	331	1300	0.01	12.0833	1486.2459	3.9006	31.307	341.0379
14	3129	331	1400	0	0	1486.2459	3.4667	27.82443	368.8623
15	3129	331	1500	0	0	1486.2459	3.1044	24.91654	393.7789
16	3129	331	1600	0	0	1486.2459	2.9255	23.48065	417.2595
17	3129	331	1700	0	0	1486.2459	2.836	22.7623	440.0218
18	3129	331	1800	0	0	1486.2459	2.7644	22.18763	462.2094
19	3129	331	1900	0	0	1486.2459	2.6168	21.00296	483.2124
20	3129	331	2000	0	0	1486.2459	2.4647	19.78218	502.9946
21	3129	331	2100	0	0	1486.2459	2.3931	19.2075	522.2021
22	3129	331	2200	0	0	1486.2459	2.2768	18.27405	540.4761
23	3129	331	2300	0	0	1486.2459	2.1829	17.52039	557.9965
24	3129	331	2400	0.05	60.4165	1546.6624	2.1158	16.98183	574.9783
25	3129	332	100	0.23	277.9159	1824.5783	3.2609	26.17264	601.151
26	3129	332	200	0.21	253.7493	2078.3276	4.3792	35.14834	636.2993
27	3129	332	300	0.26	314.1658	2392.4934	4.5358	36.40524	672.7046
28	3129	332	400	0.3	362.499	2754.9924	4.7147	37.84113	710.5457
29	3129	332	500	0.05	60.4165	2815.4089	4.4195	35.47179	746.0175
30	3129	332	600	0	0	2815.4089	4.0348	32.38411	778.4016
31	3129	332	700	0	0	2815.4089	3.2654	26.20875	804.6103
32	3129	332	800	0	0	2815.4089	2.836	22.7623	827.3726
33	3129	332	900	0	0	2815.4089	2.6481	21.25418	848.6268
34	3129	332	1000	0	0	2815.4089	2.5139	20.17706	868.8039
35	3129	332	1100	0	0	2815.4089	2.4155	19.38729	888.1912
36	3129	332	1200	0	0	2815.4089	2.2276	17.87916	906.0703
37	3129	332	1300	0	0	2815.4089	2.1695	17.41284	923.4832
38	3129	332	1400	0	0	2815.4089	2.0219	16.22817	939.7113
39	3129	332	1500	0	0	2815.4089	1.9145	15.36616	955.0775
40	3129	332	1600	0	0	2815.4089	1.8027	14.46883	969.5463
41	3129	332	1700	0	0	2815.4089	1.7311	13.89415	983.4405
42	3129	332	1800	0	0	2815.4089	1.6282	13.06826	996.5088
43	3129	332	1900	0	0	2815.4089	1.4896	11.95583	1008.465
44	3129	332	2000	0	0	2815.4089	1.4135	11.34503	1019.81
45	3129	332	2100	0	0	2815.4089	1.3241	10.62749	1030.437
46	3129	332	2200	0	0	2815.4089	1.2078	9.694044	1040.131
47	3129	332	2300	0	0	2815.4089	1.0959	8.795913	1048.927
48	3129	332	2400	0	0	2815.4089	1.0154	8.149803	1057.077
49	3129	333	100	0	0	2815.4089	0.90358	7.252314	1064.329
50	3129	333	200	0	0	2815.4089	0.84096	6.749713	1071.079
51	3129	333	300	0	0	2815.4089	0.68887	5.529008	1076.608
52	3129	333	400	0	0	2815.4089	0.62177	4.99045	1081.598
53	3129	333	500	0	0	2815.4089	0.58151	4.667316	1086.266
54	3129	333	600	0	0	2815.4089	0.53678	4.308304	1090.574
55	3129	333	700	0	0	2815.4089	0.48758	3.913415	1094.487
56	3129	333	800	0	0	2915.4089	0.43837	3.518445	1098.006
57	3129	333	900	0	0	2815.4089	0.39811	3.19531	1101.201
58	3129	333	1000	0	0	2815.4089	0.35338	2.836299	1104.037
59	3129	333	1100	0	0	2815.4089	0.30865	2.477287	1106.515
60	3129	333	1200	0	0	2815.4089	0.27286	2.190029	1108.705
61	3129	333	1300	0	0	2815.4089	0.24155	1.938729	1110.643
62	3129	333	1400	0	0	2815.4089	0.22366	1.79514	1112.439
63	3129	333	1500	0	0	2815.4089	0.20577	1.651551	1114.09
64	3129	333	1600	0	0	2815.4089	0.18787	1.507882	1115.598
65	3129	333	1700	0	0	2815.4089	0.17445	1.400171	1116.998
66	3129	333	1800	0	0	2815.4089	0.15209	1.220705	1118.219
67	3129	333	1900	0	0	2815.4089	0.12525	1.005282	1119.224
68	3129	333	2000	0	0	2815.4089	0.1163	0.933447	1120.158
69	3129	333	2100	0	0	2815.4089	0.11183	0.89757	1121.055
70	3129	333	2200	0	0	2815.4089	0.08946	0.718024	1121.773
71	3129	333	2300	0	0	2815.4089	0.09394	0.753981	1122.527
72	3129	333	2400	0	0	2815.4089	0.09394	0.753981	1123.281
73	3129	334	100	0	0	2815.4089	0.08499	0.682147	1123.963
74	3129	334	200	0	0	2815.4089	0.07157	0.574435	1124.538
75	3129	334	300	0	0	2815.4089	0.0671	0.538558	1125.076
76	3129	334	400	0	0	2815.4089	0.04473	0.359012	1125.435

US-31, Hamilton County (DATA SET 2 for Rain and Flow)

77	3129	334	500	0	0	2815.4089	0.04473	0.359012	1125.794
78	3129	334	600	0	0	2815.4089	0.02237	0.179546	1125.974
79	3129	334	700	0	0	2815.4089	0	0	1125.974
80	3129	334	800	0	0	2815.4089	0	0	1125.974
81	3129	334	900	0	0	2815.4089	0.01789	0.143589	1126.118
82	3129	334	1000	0	0	2815.4089	0.05815	0.466724	1126.584
83	3129	334	1100	0	0	2815.4089	0.07157	0.574435	1127.159
84	3129	334	1200	0	0	2815.4089	0.0671	0.538558	1127.697
85	3129	334	1300	0	0	2815.4089	0.05815	0.466724	1128.164
86	3129	334	1400	0	0	2815.4089	0.07157	0.574435	1128.738
87	3129	334	1500	0	0	2815.4089	0.07157	0.574435	1129.313
88	3129	334	1600	0	0	2815.4089	0.0492	0.394889	1129.708
89	3129	334	1700	0	0	2815.4089	0.06262	0.502601	1130.21
90	3129	334	1800	0	0	2815.4089	0.06262	0.502601	1130.713
91	3129	334	1900	0	0	2815.4089	0.06262	0.502601	1131.216
92	3129	334	2000	0	0	2815.4089	0.0671	0.538558	1131.754
93	3129	334	2100	0	0	2815.4089	0.0671	0.538558	1132.293
94	3129	334	2200	0	0	2815.4089	0.0671	0.538558	1132.831
95	3129	334	2300	0	0	2815.4089	0.05815	0.466724	1133.298
96	3129	334	2400	0	0	2815.4089	0.0492	0.394889	1133.693
97	3129	335	100	0	0	2815.4089	0.0492	0.394889	1134.088
98	3129	335	200	0	0	2815.4089	0.03579	0.287258	1134.375
99	3129	335	300	0	0	2815.4089	0.04026	0.323135	1134.698
100	3129	335	400	0	0	2815.4089	0.04473	0.359012	1135.057
101	3129	335	500	0	0	2815.4089	0.03579	0.287258	1135.344
102	3129	335	600	0	0	2815.4089	0.03579	0.287258	1135.632
103	3129	335	700	0	0	2815.4089	0.04026	0.323135	1135.955
104	3129	335	800	0	0	2815.4089	0.04026	0.323135	1136.278
105	3129	335	900	0	0	2815.4089	0.04026	0.323135	1136.601
106	3129	335	1000	0	0	2815.4089	0.03131	0.2513	1136.852
107	3129	335	1100	0	0	2815.4089	0.03131	0.2513	1137.104
108	3129	335	1200	0	0	2815.4089	0.03579	0.287258	1137.391
109	3129	335	1300	0	0	2815.4089	0.02684	0.215423	1137.606
			CUMUL.	2.33	2815.409		141.7366	1137.606	
		VOLUME IN CFT		2815.417			1137.606		
Outflow vol. as percentage of precip. volume							40.40632		

US-31, Hamilton County (DATA SET 3 for rain and flow)

TOT.HRS	RTE/CNT	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	3129	337	100	0.02	24.1666	24.1666	0.00447	0.035877	0.035877
2	3129	337	200	0.15	181.2495	205.4161	0	0	0.035877
3	3129	337	300	0.3	362.499	567.9151	0	0	0.035877
4	3129	337	400	0.26	314.1658	882.0809	0	0	0.035877
5	3129	337	500	0.23	277.9159	1159.9968	0	0	0.035877
6	3129	337	600	0.48	579.9984	1739.9952	0.40258	3.231188	3.267065
7	3129	337	700	0.09	108.7497	1848.7449	4.6655	37.44624	40.7133
8	3129	337	800	0.01	12.0833	1860.8282	4.5045	36.15402	76.86732
9	3129	337	900	0.01	12.0833	1872.9115	3.7127	29.79887	106.6662
10	3129	337	1000	0.12	144.9996	2017.9111	3.2296	25.92142	132.5876
11	3129	337	1100	0.02	24.1666	2042.0777	3.8067	30.55334	163.1409
12	3129	337	1200	0	0	2042.0777	2.8986	23.26474	186.4057
13	3129	337	1300	0	0	2042.0777	0	0	186.4057
14	3129	337	1400	0	0	2042.0777	1.588	12.74561	199.1513
15	3129	337	1500	0	0	2042.0777	2.4781	19.88973	219.041
16	3129	337	1600	0	0	2042.0777	2.3753	19.06463	238.1057
17	3129	337	1700	0	0	2042.0777	2.2813	18.31017	256.4158
18	3129	337	1800	0	0	2042.0777	2.1695	17.41284	273.8287
19	3129	337	1900	0	0	2042.0777	2.0934	16.80205	290.6307
20	3129	337	2000	0	0	2042.0777	2.0442	16.40716	307.0379
21	3129	337	2100	0	0	2042.0777	1.9369	15.54595	322.5838
22	3129	337	2200	0	0	2042.0777	1.834	14.72005	337.3039
23	3129	337	2300	0	0	2042.0777	1.749	14.03782	351.3417
24	3129	337	2400	0	0	2042.0777	1.6819	13.49927	364.841
25	3129	338	100	0	0	2042.0777	1.6103	12.92459	377.7655
26	3129	338	200	0	0	2042.0777	1.5388	12.35072	390.1163
27	3129	338	300	0	0	2042.0777	1.4538	11.66849	401.7847
28	3129	338	400	0	0	2042.0777	1.3598	10.91403	412.6988
29	3129	338	500	0	0	2042.0777	1.2525	10.05282	422.7516
30	3129	338	600	0	0	2042.0777	1.1585	9.298353	432.0499
31	3129	338	700	0	0	2042.0777	1.0557	8.473259	440.5232
32	3129	338	800	0	0	2042.0777	0.95278	7.647203	448.1704
33	3129	338	900	0	0	2042.0777	0.88569	7.108725	455.2791
34	3129	338	1000	0	0	2042.0777	0.81859	6.570167	461.8493
35	3129	338	1100	0	0	2042.0777	0.75596	6.067486	467.9168
36	3129	338	1200	0	0	2042.0777	0.72913	5.852143	473.7689
37	3129	338	1300	0	0	2042.0777	0.69781	5.600763	479.3697
38	3129	338	1400	0	0	2042.0777	0.65308	5.241751	484.6114
39	3129	338	1500	0	0	2042.0777	0.58598	4.703193	489.3146
40	3129	338	1600	0	0	2042.0777	0.50547	4.057003	493.3716
41	3129	338	1700	0	0	2042.0777	0.47416	3.805703	497.1773
42	3129	338	1800	0	0	2042.0777	0.43837	3.518445	500.6958
43	3129	338	1900	0	0	2042.0777	0.38917	3.123556	503.8193
44	3129	338	2000	0	0	2042.0777	0.35338	2.836299	506.6556
45	3129	338	2100	0	0	2042.0777	0.32207	2.584998	509.2406
46	3129	338	2200	0	0	2042.0777	0.29076	2.333698	511.5743
47	3129	338	2300	0	0	2042.0777	0.25497	2.04644	513.6208
48	3129	338	2400	0	0	2042.0777	0.2326	1.866894	515.4877
49	3129	339	100	0	0	2042.0777	0.21024	1.687428	517.1751
50	3129	339	200	0	0	2042.0777	0.18787	1.507882	518.683
51	3129	339	300	0	0	2042.0777	0.16998	1.364293	520.0473
52	3129	339	400	0	0	2042.0777	0.15656	1.256582	521.3039
53	3129	339	500	0	0	2042.0777	0.15209	1.220705	522.5246
54	3129	339	600	0	0	2042.0777	0.12972	1.041159	523.5657
55	3129	339	700	0	0	2042.0777	0.12972	1.041159	524.6069
56	3129	339	800	0	0	2042.0777	0.1163	0.933447	525.5403
57	3129	339	900	0	0	2042.0777	0.11183	0.89757	526.4379
58	3129	339	1000	0	0	2042.0777	0.10736	0.861693	527.2996
59	3129	339	1100	0	0	2042.0777	0.10736	0.861693	528.1613
60	3129	339	1200	0	0	2042.0777	0.10288	0.825735	528.987
61	3129	339	1300	0	0	2042.0777	0.10288	0.825735	529.8128
62	3129	339	1400	0	0	2042.0777	0.10736	0.861693	530.6744
63	3129	339	1500	0	0	2042.0777	0.10736	0.861693	531.5361
64	3129	339	1600	0	0	2042.0777	0.10736	0.861693	532.3978
65	3129	339	1700	0	0	2042.0777	0.10736	0.861693	533.2595
66	3129	339	1800	0	0	2042.0777	0.11183	0.89757	534.1571
67	3129	339	1900	0	0	2042.0777	0.10288	0.825735	534.9828
68	3129	339	2000	0	0	2042.0777	0.09394	0.753981	535.7368
69	3129	339	2100	0	0	2042.0777	0.08946	0.718024	536.4548
70	3129	339	2200	0	0	2042.0777	0.07604	0.610312	537.0651
71	3129	339	2300	0	0	2042.0777	0.0671	0.538558	537.6037
72	3129	339	2400	0	0	2042.0777	0.05815	0.466724	538.0704
73	3129	340	100	0	0	2042.0777	0.04473	0.359012	538.4294
74	3129	340	200	0	0	2042.0777	0.0492	0.394889	538.8243
75	3129	340	300	0	0	2042.0777	0.04026	0.323135	539.1475
76	3129	340	400	0	0	2042.0777	0.02684	0.215423	539.3629

US-31, Hamilton County (DATA SET 3 for rain and flow)

77	3129	340	500	0	0	2042.0777	0.01342	0.107712	539.4706
78	3129	340	600	0	0	2042.0777	0.00895	0.071834	539.5424
79	3129	340	700	0	0	2042.0777	0.01342	0.107712	539.6501
80	3129	340	800	0	0	2042.0777	0.01342	0.107712	539.7579
81	3129	340	900	0	0	2042.0777	0.00895	0.071834	539.8297
82	3129	340	1000	0	0	2042.0777	0.00447	0.035877	539.8656
83	3129	340	1100	0	0	2042.0777	0.02237	0.179546	540.0451
84	3129	340	1200	0	0	2042.0777	0.01342	0.107712	540.1528
85	3129	340	1300	0	0	2042.0777	0.01342	0.107712	540.2605
86	3129	340	1400	0	0	2042.0777	0.01342	0.107712	540.3682
87	3129	340	1500	0	0	2042.0777	0.00447	0.035877	540.4041
88	3129	340	1600	0	0	2042.0777	0.01342	0.107712	540.5118
89	3129	340	1700	0	0	2042.0777	0.01342	0.107712	540.6195
90	3129	340	1800	0	0	2042.0777	0.02237	0.179546	540.7991
91	3129	340	1900	0	0	2042.0777	0.01342	0.107712	540.9068
92	3129	340	2000	0	0	2042.0777	0.02237	0.179546	541.0864
93	3129	340	2100	0	0	2042.0777	0.01789	0.143589	541.2299
94	3129	340	2200	0	0	2042.0777	0.01342	0.107712	541.3377
95	3129	340	2300	0	0	2042.0777	0.02237	0.179546	541.5172
96	3129	340	2400	0	0	2042.0777	0.01342	0.107712	541.6249
97	3129	341	100	0	0	2042.0777	0.01342	0.107712	541.7326
98	3129	341	200	0	0	2042.0777	0.00895	0.071834	541.8045
99	3129	341	300	0	0	2042.0777	0.00895	0.071834	541.8763
100	3129	341	400	0	0	2042.0777	0.00895	0.071834	541.9481
101	3129	341	500	0	0	2042.0777	0.00895	0.071834	542.02
			CUMUL	1.69	2042.078		67.53133	542.02	
		VOLUME IN CFT		2042.083			542.02		
	Outflow vol. as percentage of precip. volume						26.5425		

US-36, Hendricks County (DATA SET 1 for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	3632	331	2200	0.01	9.6667	9.6667	0	0	0
2	3632	331	2300	0.01	9.6667	19.3334	0	0	0
3	3632	331	2400	0.06	58.0002	77.3336	0	0	0
4	3632	332	100	0.06	58.0002	135.3338	0.95325	7.650975	7.650975
5	3632	332	200	0.02	19.3334	154.6672	3.1852	25.56505	33.21603
6	3632	332	300	0.09	87.0003	241.6675	2.967	23.81374	57.02976
7	3632	332	400	0	0	241.6675	2.8023	22.49182	79.52158
8	3632	332	500	0.01	9.6667	251.3342	2.5535	20.4943	100.0165
9	3632	332	600	0	0	251.3342	1.5734	12.62842	112.6449
10	3632	332	700	0	0	251.3342	1.1944	9.586493	122.2314
11	3632	332	800	0	0	251.3342	0.95708	7.681715	129.9131
12	3632	332	900	0	0	251.3342	0.80395	6.452663	136.3658
13	3632	332	1000	0	0	251.3342	0.69293	5.561595	141.9274
14	3632	332	1100	0	0	251.3342	0.6087	4.885546	146.8129
15	3632	332	1200	0	0	251.3342	0.52831	4.240322	151.0532
16	3632	332	1300	0	0	251.3342	0.47471	3.810117	154.8634
17	3632	332	1400	0	0	251.3342	0.42494	3.410653	158.274
18	3632	332	1500	0	0	251.3342	0.37135	2.980529	161.2545
19	3632	332	1600	0	0	251.3342	0.31392	2.519585	163.7741
20	3632	332	1700	0	0	251.3342	0.29095	2.335223	166.1094
21	3632	332	1800	0	0	251.3342	0.27947	2.243022	168.3524
22	3632	332	1900	0	0	251.3342	0.26415	2.120121	170.4726
23	3632	332	2000	0	0	251.3342	0.25267	2.02795	172.5005
24	3632	332	2100	0	0	251.3342	0.21822	1.751477	174.252
25	3632	332	2200	0	0	251.3342	0.08422	0.675957	174.928
26	3632	332	2300	0	0	251.3342	0.03828	0.307243	175.2352
27	3632	332	2400	0	0	251.3342	0.02297	0.184362	175.4196
28	3632	333	100	0	0	251.3342	0.00766	0.061481	175.4811
29	3632	333	200	0	0	251.3342	0	0	175.4811
30	3632	333	300	0	0	251.3342	0	0	175.4811
31	3632	333	400	0	-0	251.3342	0	0	175.4811
			CUMUL.	0.26			21.86353		
			VOLUME IN CFT	251.3333			175.4811		
	Outflow vol. as percentage of precip. volume						69.82005		

US-36, Hendricks County (DATA SET 2 for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	3632	334	200	0.03	29.0001	29.0001	0.0268	0.215102	0.215102
2	3632	334	300	0.45	435.0015	464.0016	4.7012	37.73277	37.94787
3	3632	334	400	0	0	464.0016	5.4171	43.47873	81.4266
4	3632	334	500	0.01	9.6667	473.6683	2.5076	20.1265	101.5531
5	3632	334	600	0	0	473.6683	1.4203	11.39961	112.9527
6	3632	334	700	0	0	473.6683	1.0336	8.29588	121.2486
7	3632	334	800	0	0	473.6683	0.82692	6.637025	127.8856
8	3632	334	900	0	0	473.6683	0.66996	5.377233	133.2629
8	3632	334	1000	0	0	473.6683	0.56276	4.516824	137.7797
10	3632	334	1100	0	0	473.6683	0.49768	3.994479	141.7742
11	3632	334	1200	0	0	473.6683	0.43643	3.502874	145.277
12	3632	334	1300	0	0	473.6683	0.35986	2.883308	148.1653
13	3632	334	1400	0	0	473.6683	0.29861	2.396704	150.562
14	3632	334	1500	0	0	473.6683	0.22204	1.782137	152.3442
15	3632	334	1600	0	0	473.6683	0.16079	1.290533	153.6347
16	3632	334	1700	0	0	473.6683	0.09954	0.798928	154.4336
17	3632	334	1800	0	0	473.6683	0.06891	0.553085	154.9867
18	3632	334	1900	0	0	473.6683	0.02297	0.184362	155.1711
18	3632	334	2000	0	0	473.6683	0.01531	0.122881	155.294
20	3632	334	2100	0	0	473.6683	0.00766	0.061481	155.3554
21	3632	334	2200	0	0	473.6683	0.00766	0.061481	155.4169
22	3632	334	2300	0	0	473.6683	0.00766	0.061481	155.4784
23	3632	334	2400	0	0	473.6683	0.00766	0.061481	155.5399
24	3632	335	100	0	0	473.6683	0.00766	0.061481	155.6014
25	3632	335	200	0	0	473.6683	0.00766	0.061481	155.6629
26	3632	335	300	0	0	473.6683	0.00766	0.061481	155.7243
27	3632	335	400	0	0	473.6683	0.01531	0.122881	155.8472
28	3632	335	500	0	0	473.6683	0.02297	0.184362	156.0316
29	3632	335	600	0	0	473.6683	0.0268	0.215102	156.2467
30	3632	335	700	0	0	473.6683	0.0268	0.215102	156.4616
31	3632	335	800	0	0	473.6683	0.02297	0.184362	156.6461
32	3632	335	900	0	0	473.6683	0.02297	0.184362	156.8305
33	3632	335	1000	0	0	473.6683	0.02297	0.184362	157.0149
34	3632	335	1100	0	0	473.6583	0.01914	0.153621	157.1685
35	3632	335	1200	0	0	473.6683	0.01914	0.153621	157.3221
36	3632	335	1300	0	0	473.6683	0.01531	0.122881	157.445
37	3632	335	1400	0	0	473.6683	0.02297	0.184362	157.6294
38	3632	335	1500	0	0	473.6683	0.03063	0.245843	157.8752
39	3632	335	1600	0	0	473.6683	0.00766	0.061481	157.9367
40	3632	335	1700	0	0	473.6683	0	0	157.9367
41	3632	335	1800	0	0	473.6583	0	0	157.9367
42	3632	335	1900	0	0	473.6663	0	0	157.9367
43	3632	335	2000	0	0	473.6683	0	0	157.9367
44	3632	335	2100	0	0	473.6683	0.02297	0.184362	158.121
45	3632	335	2200	0	0	473.6683	0.03445	0.276503	158.3975
46	3632	335	2300	0.01	9.6667	483.335	0.03063	0.245843	158.6434
47	3632	335	2400	0	0	483.335	0.03445	0.276503	158.9199
48	3632	336	100	0.01	9.6667	493.0017	0.03445	0.276503	159.1964
49	3632	336	200	0.01	9.6667	502.6684	0.03063	0.245843	159.4422
50	3632	336	300	0	0	502.6684	0.0268	0.215102	159.6573
51	3632	336	400	0	0	502.6684	0.02297	0.184362	159.8417
52	3632	336	500	0	0	502.6684	0.0268	0.215102	160.0568
53	3632	336	600	0	0	502.6684	0.0268	0.215102	160.2719
54	3632	336	700	0	0	502.6684	0.0268	0.215102	160.487
55	3632	336	800	0	0	502.6684	0.0268	0.215102	160.7021
56	3632	336	900	0	0	502.6664	0.0268	0.215102	160.9172
57	3632	336	1000	0	0	502.6684	0.02297	0.184362	161.1016
58	3632	336	1100	0	0	502.6684	0.0268	0.215102	161.3167
59	3632	336	1200	0	0	502.6684	0.02297	0.184362	161.501
			CUMUL	0.52			20.12173		
			VOLUME IN CFT	502.6667			161.501		
			Outflow vol. as percentage of precip. volume				32.12885		

US-36, Hendricks County (DATA SET 3 for Rain and flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	3632	336	1400	0.01	9.6667	9.6667	0.00766	0.061481	0.061481
2	3632	336	1500	0.05	48.3335	58.0002	0.00766	0.061481	0.122961
3	3632	336	1600	0.17	164.3339	222.3341	1.2404	9.955698	10.07866
4	3632	336	1700	0.11	106.3337	328.6678	0	0	10.07866
5	3632	336	1800	0.03	29.0001	357.6679	2.2357	17.94418	28.02284
6	3632	336	1900	0	0	357.6679	3.2388	25.99526	54.01809
7	3632	336	2000	0	0	357.6679	1.9333	15.51705	69.53514
8	3632	336	2100	0	0	357.6679	1.4012	11.24631	80.78146
9	3632	336	2200	0.01	9.6667	367.3346	1.1791	9.463692	90.24515
10	3632	336	2300	0	0	367.3346	1.0298	8.265381	98.51053
11	3632	336	2400	0	0	367.3346	0.93794	7.528094	106.0386
12	3632	337	100	0.01	9.6667	377.0013	0.9188	7.374473	113.4131
13	3632	337	200	0	0	377.0013	0.92263	7.405213	120.8183
14	3632	337	300	0	0	377.0013	0.8384	6.729166	127.5475
			CUMUL	0.39			15.89139		
		VOLUME IN CFT		377			127.5475		
	Outflow vol. as percentage of precip. volume						33.83222		

US-41, Sullivan County (DATA SET 1 for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM RAIN cft	FLOW gpm	FLOW cft	CUM FLOW cft
1	4177	2	300	0.11	50.27	50.27	0.19927	1.59938087	1.59938087
2	4177	2	400	0.07	31.99	82.26	1.3501	10.8361726	12.4355535
3	4177	2	500	0.04	18.28	100.54	1.3706	10.9999071	23.4354606
4	4177	2	600	0.01	4.57	105.11	1.6958	13.61083	37.0462906
6	4177	2	700	0.03	13.71	118.82	1.8219	14.6229336	51.6692243
6	4177	2	800	0	0	118.82	1.403	11.2607586	62.9299829
7	4177	2	900	0.02	9.14	127.96	0.244	1.9583928	64.8883757
8	4177	2	1000	0.02	9.14	137.1	0.7686	6.16893732	71.0573131
9	4177	2	1100	0.05	22.85	159.95	2.0293	16.2875677	87.3448807
10	4177	2	1200	0.07	31.99	191.94	1.4315	11.4895053	98.834366
11	4177	2	1300	0.01	4.57	196.51	1.7324	13.9045889	112.738975
12	4177	2	1400	0	0	196.51	0.4636	3.72094632	116.459921
13	4177	2	1500	0.01	4.57	201.08	0	0	116.459921
14	4177	2	1600	0.03	13.71	214.79	0.82553	6.62586889	123.08579
15	4177	2	1700	0.07	31.99	246.78	1.2078	9.69404436	132.779834
16	4177	2	1800	0.07	31.99	278.77	1.2363	9.92279106	142.702626
17	4177	2	1900	0.05	22.85	301.62	1.3095	10.5103089	153.212934
18	4177	. 2	2000	0.02	9.14	310.76	1.3176	10.5753211	163.788256
19	4177	2	2100	0.05	22.85	333.61	1.4477	11.6196297	175.407785
20	4177	2	2200	0	0	333.61	1.5169	12.1749428	187.582728
21	4177	2	2300	0.01	4.57	338.18	0.38633	3.10076185	190.68349
22	4177	2	2400	0.01	4.57	342.75	0.37413	3.00284221	193.686332
23	4177	3	100	0	0	342.75	0.27247	2.18689671	195.873231
24	4177	3	200	0.01	4.57	347.32	0.22367	1.79522015	197.668451
25	4177	3	300	0	0	347.32	0.2074	1.66463388	199.333085
26	4177	3	400	0	0	347.32	0.15453	1.24028869	200.573374
27	4177	3	500	0	0	347.32	0.11793	0.94652977	201.519903
28	4177	3	600	0	0	347.32	0.10573	0.84861013	202.368513
29	4177	3	700	0	0	347.32	0.05693	0.45693157	202.825445
30	4177	3	800	0	0	347.32	0.02033	0.16317265	202.988618
31	4177	3	900	0	0	347.32	0.0244	0.19583928	203.184457
32	4177	3	1000	0	0	347.32	0.03253	0.26109229	203.445549
33	4177	3	1100	0	0	347.32	0.03253	0.26109229	203.706642
34	4177	3	1200	0	0	347.32	0.02847	0.22850591	203.935147
35	4177	3	1300	0	0	347.32	0.02847	0.22850591	204.163653
35	4177	3	1400	0	0	347.32	0.02033	0.16317265	204.326826
37	4177	3	1500	0	0	347.32	0.0244	0.19583926	204.522665
38	4177	3	1600	0	0	347.32	0.02847	0.22850591	204.751171
39	4177	3	1700	0	0	347.32	0.0244	0.19583928	204.94701
40	4177	3	1800	0	0	347.32	0.03253	0.26109229	205.208103
41	4177	3	1900	0	0	347.32	0.03253	0.26109229	205.469195
42	4177	3	2000	0	0	347.32	0.0244	0.19583928	205.665034
43	4177	3	2100	0	0	347.32	0.02847	0.22850591	205.89354
44	4177	3	2200	0	0	347.32	0.02033	0.16317265	206.056713
45	4177	3	2300	0	0	347.32	0.0244	0.19583928	206.252552
46	4177	3	2400	0	0	347.32	0.01627	0.13058627	206.383138
47	4177	4	100	0	0	347.32	0.02033	0.16317265	206.546311
48	4177	4	200	0	0	347.32	0.01627	0.13058627	206.676897
49	4177	4	300	0	0	347.32	0.01627	0.13058627	206.807484
50	4177	4	400	0	0	347.32	0.01627	0.13058627	206.93807
61	4177	4	500	0	0	347.32	0.0122	0.09791964	207.03599
52	4177	4	600	0	0	347.32	0.0122	0.09791964	207.133909
53	4177	4	700	0	0	347.32	0.0122	0.09791964	207.231829
54	4177	4	800	0	0	347.32	0.00813	0.06525301	207.297082
55	4177	4	900	0	0	347.32	0.00813	0.06525301	207.362335
55	4177	4	1000	0	0	347.32	0.00813	0.06525301	207.427588
57	4177	4	1100	0	0	347.32	0.00813	0.06525301	207.492841
58	4177	4	1200	0	0	347.32	0.00813	0.06525301	207.558094
59	4177	4	1300	0	0	347.32	0.00813	0.06525301	207.623347
60	4177	4	1400	0	0	347.32	0.0122	0.09791964	207.721266
61	4177	4	1500	0	0	347.32	0.00813	0.06525301	207.786519
62	4177	4	1600	0	0	347.32	0.00813	0.06525301	207.851772
63	4177	4	1700	0	0	347.32	0.00813	0.06525301	207.917025
64	4177	4	1800	0	0	347.32	0.00813	0.06525301	207.982279
65	4177	4	1500	0	0	347.32	0.00813	0.06525301	208.047532
66	4177	4	2000	0	0	347.32	0.00407	0.03266663	208.080196
67	4177	4	2100	0	0	347.32	0.00407	0.03266663	208.112865
			CUMUL	0.76			25.92919		
			VOLUME IN CFT	347.32			206.112865		
			Outflow vol. as percentage of precip. volume				59.9196317		

US-41, Sullivan County (DATA SET 2 for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	4177	8	900	0.02	11.54	11.54	0	0	0
2	4177	8	1000	0.06	34.62	46.16	0.0488	0.391679	0.391679
3	4177	8	1100	0.14	80.78	126.94	1.7161	13.77376	14.16544
4	4177	8	1200	0.02	11.54	138.48	1.4152	11.35868	25.52412
5	4177	8	1300	0.05	28.85	167.33	1.4925	11.9791	37.50322
6	4177	8	1400	0	0	167.33	1.0167	8.160238	45.66346
7	4177	8	1500	0	0	167.33	0.23587	1.89314	47.5566
8	4177	8	1600	0	0	167.33	0.15047	1.207702	48.7643
9	4177	8	1700	0	0	167.33	0.11387	0.913943	49.67825
10	4177	8	1800	0	0	167.33	0.06913	0.554851	50.2331
11	4177	8	1900	0	0	167.33	0.0244	0.195839	50.42894
12	4177	8	2000	0	0	167.33	0.0244	0.195839	50.62477
13	4177	8	2100	0.01	5.77	173.1	0.03253	0.261092	50.88587
14	4177	8	2200	0	0	173.1	0.10167	0.816024	51.70189
15	4177	8	2300	0	0	173.1	0.13827	1.109783	52.81167
16	4177	8	2400	0	0	173.1	0.11387	0.913943	53.72562
17	4177	9	100	0.01	5.77	178.87	0.1342	1.077116	54.80273
18	4177	9	200	0	0	178.87	0.12607	1.011863	55.8146
19	4177	9	300	0	0	178.87	0.07727	0.620184	56.43478
20	4177	9	400	0	0	178.87	0.0244	0.195839	56.63062
21	4177	9	500	0	0	178.87	0.02847	0.228506	56.85913
22	4177	9	600	0	0	178.87	0.02847	0.228506	57.08763
23	4177	9	700	0	0	178.87	0.02033	0.163173	57.2508
24	4177	9	800	0	0	178.87	0.02847	0.228506	57.47931
25	4177	9	900	0	0	178.87	0.02847	0.228506	57.70782
26	4177	9	1000	0	0	178.87	0.02847	0.228506	57.93632
27	4177	9	1100	0	0	178.87	0.03253	0.261092	58.19741
28	4177	9	1200	0	0	178.87	0.0244	0.195839	58.39325
29	4177	9	1300	0	0	178.87	0.02847	0.228506	58.62176
30	4177	9	1400	0	0	178.87	0.02033	0.163173	58.78493
31	4177	9	1500	0	0	178.87	0.0244	0.195839	58.98077
32	4177	9	1600	0	0	178.87	0.02033	0.163173	59.14394
33	4177	9	1700	0	0	178.87	0.02033	0.163173	59.30712
34	4177	9	1800	0	0	178.87	0.01627	0.130586	59.4377
35	4177	9	1900	0	0	178.87	0.01627	0.130586	59.56829
36	4177	9	2000	0	0	178.87	0.0122	0.09792	59.66621
37	4177	9	2100	0	0	178.87	0.0122	0.09792	59.76413
38	4177	9	2200	0	0	178.87	0.0122	0.09792	59.86205
39	4177	9	2300	0	0	178.87	0.00813	0.065253	59.9273
40	4177	9	2400	0	0	178.87	0.0122	0.09792	60.02522
41	4177	10	100	0	0	178.87	0.00813	0.065253	60.09047
42	4177	10	200	0	0	178.87	0.00813	0.065253	60.15573
43	4177	10	300	0	0	178.87	0.00813	0.065253	60.22098
44	4177	10	400	0	0	178.87	0.01627	0.130586	60.35157
45	4177	10	500	0	0	178.87	0.0244	0.195839	60.54741
46	4177	10	600	0	0	178.87	0.01627	0.130586	60.67799
47	4177	10	700	0	0	178.87	0.01627	0.130586	60.80858
48	4177	10	800	0	0	178.87	0.01627	0.130586	60.93916
49	4177	10	900	0	0	178.87	0.0122	0.09792	61.03708
50	4177	10	1000	0	0	178.87	0.0122	0.09792	61.135
51	4177	10	1100	0	0	178.87	0.0122	0.09792	61.23292
52	4177	10	1200	0	0	178.87	0.00813	0.065253	61.29818
53	4177	10	1300	0	0	178.87	0.0122	0.09792	61.3961
54	4177	10	1400	0	0	178.87	0.00813	0.065253	61.46135
55	4177	10	1500	0	0	178.87	0.0122	0.09792	61.55927
56	4177	10	1600	0	0	178.87	0.0122	0.09792	61.65719
57	4177	10	1700	0	0	178.87	0.00813	0.065253	61.72244
58	4177	10	1800	0	0	178.87	0.01627	0.130586	61.85303
59	4177	10	1900	0	0	178.87	0.00407	0.032667	61.88569
60	4177	10	2000	0	0	178.87	0.00813	0.065253	61.95095
			CUMUL	0.31			7.71859		
		VOLUME IN CFT		178.87			61.95095		
Outflow vol. as percentage of precip. volume							34 63462		

SR-9, Noble County (DATA SET for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	957	277	200	0.59	427.75	427.75	0	0	0
2	957	277	300	0.88	638	1065.75	0.3373	2.707237	2.707237
3	957	277	400	0.21	152.25	1218	0.05741	0.460784	3.168021
4	957	277	500	0.26	188.5	1406.5	0.05741	0.460784	3.628805
5	957	277	600	0.08	58	1464.5	0.06818	0.547226	4.176032
6	957	277	700	0.01	7.25	1471.75	0.40189	3.22565	7.401681
7	957	277	800	0.01	7.25	1479	0.75355	6.048143	13.44982
8	957	277	900	0	0	1479	1.0155	8.150606	21.60043
9	957	277	1000	0	0	1479	1.2774	10.25267	31.8531
10	957	277	1100	0	0	1479	1.5071	12.09629	43.94938
11	957	277	1200	0	0	1479	1.6255	13.04659	56.99597
12	957	277	1300	0	0	1479	1.6722	13.42141	70.41738
13	957	277	1400	0	0	1479	1.6901	13.56508	83.98246
14	957	277	1500	0	0	1479	1.6793	13.4784	97.46086
15	957	277	1600	0	0	1479	1.6578	13.30583	110.7667
16	957	277	1700	0	0	1479	1.6363	13.13327	123.9
17	957	277	1800	0	0	1479	1.5968	12.81624	136.7162
18	957	277	1900	0	0	1479	1.5609	12.5281	149.2443
19	957	277	2000	0	0	1479	1.4999	12.0385	161.2828
20	957	277	2100	0	0	1479	1.4497	11.63558	172.9184
21	957	277	2200	0	0	1479	1.3994	11.23186	184.1502
22	957	277	2300	0	0	1479	1.3456	10.80005	194.9503
23	957	277	2400	0	0	1479	1.2954	10.39714	205.3474
24	957	278	100	0	0	1479	1.2523	10.05121	215.3986
25	957	278	200	0	0	1479	1.1985	9.619401	225.018
26	957	278	300	0	0	1479	1.22	9.791964	234.81
27	957	278	400	0	0	1479	1.2846	10.31046	245.1205
28	957	278	500	0	0	1479	1.2595	10.109	255.2295
56	957	279	900	0	0	1479	0.3423	2.747368	257.9768
97	957	281	300	0	0	1479	0.006	0.048157	258.025
			CUMUL.	2.04			32.14784		
		VOLUME IN CFT		1479			258.025		
Outflow vol. as percentage of precip. volume							17.44591		

SR-63, Vermillion County (DATA SET 1 for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	6383	276	200	0.07	20.9769	20.9769	0	0	0
2	6383	276	300	0.11	32.9637	53.9406	0.50512	4.054194	4.054194
3	6383	276	400	0.03	8.9901	62.9307	1.5924	12.78092	16.83512
4	6383	276	500	0.01	2.9967	65.9274	0.63448	5.092463	21.92758
5	6383	276	600	0	0	65.9274	0.4774	3.831708	25.75929
6	6383	276	700	0	0	65.9274	0.38808	3.114808	28.87409
7	6383	276	800	0	0	65.9274	0.24948	2.002376	30.87647
8	6383	276	900	0	0	65.9274	0.15092	1.211314	32.08778
9	6383	276	1000	0	0	65.9274	0.09856	0.791062	32.87885
10	6383	276	1100	0	0	65.9274	0.07392	0.593297	33.47214
11	6383	276	1200	0	0	65.9274	0.01232	0.098883	33.57103
12	6383	276	1300	0	0	65.9274	0.02464	0.197766	33.76879
13	6383	276	1400	0	0	65.9274	0.01848	0.148324	33.91712
14	6383	276	1500	0	0	65.9274	0.02464	0.197766	34.11488
15	6383	276	1600	0	0	65.9274	0.02464	0.197766	34.31265
16	6383	276	1700	0	0	65.9274	0.01848	0.148324	34.46097
17	6383	276	1800	0	0	65.9274	0.01848	0.148324	34.6093
18	6383	276	1900	0	0	65.9274	0.01232	0.098883	34.70818
19	6383	276	2000	0	0	65.9274	0.00616	0.049441	34.75762
20	6383	276	2100	0.01	2.9967	68.9241	0.00924	0.074162	34.83178
21	6383	276	2200	0	0	68.9241	0.00308	0.024721	34.8565
22	6383	276	2300	0	0	68.9241	0.00616	0.049441	34.90594
			CUMUL.	0.23			4.349		
		VOLUME IN CFT		68.92333			34.90594		
	Outflow vol. as percentage of precip. volume						50.6446		

SR-63, Vermillion County (DATA SET 2 for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	6383	277	500	0.29	86.9043	86.9043	0.68992	5.537436	5.537436
2	6383	277	600	0.09	26.9703	113.8746	3.0122	24.17652	29.71396
3	6383	277	700	0.02	5.9934	119.868	1.3675	10.97583	40.68978
4	6383	277	800	0	0	119.868	0.48356	3.881143	44.57093
5	6383	277	900	0	0	119.868	0.32648	2.620334	47.19133
6	6383	277	1000	0	0	119.868	0.19096	1.532683	48.72401
7	6383	277	1100	0	0	119.868	0.09856	0.791052	49.51507
8	6383	277	1200	0	0	119.868	0.03388	0.271923	49.787
9	6383	277	1300	0	0	119.868	0.02156	0.173043	49.96005
10	6383	277	1400	0	0	119.868	0.00616	0.049441	50.00949
			CUMUL	0.4			6.23078		
		VOLUME IN CFT		119.8667			50.00949		
	Outflow vol. as percentage of precip. volume						41.72093		

US-30, Laporte County (DATA SET 1 for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	3046	275	2200	0.04	20	20	0	0	0
2	3046	275	2300	0.1	50	70	0	0	0
3	3046	275	2400	0.08	40	110	0	0	0
4	3046	276	100	0.07	35	145	0.0467	0.374824	0.374824
5	3046	276	200	0.01	5	150	0.09729	0.780869	1.155693
6	3046	276	300	0	0	150	0.05837	0.468489	1.624182
7	3046	276	400	0	0	150	0.01946	0.15619	1.780372
8	3046	276	500	0	0	150	0.01167	0.093666	1.874037
9	3046	276	600	0	0	150	0.00778	0.062444	1.936481
10	3046	276	700	0	0	150	0.00389	0.031222	1.967703
11	3046	276	800	0	0	150	0.00389	0.031222	1.998925
12	3046	276	900	0	0	150	0.00389	0.031222	2.030147
			CUM.	0.3			0.25294		
		VOLUME IN CFT		150			2.030147		
	Outflow vol. as percentage of precip. volume						1.353431		

US-30, Laporte County (DATA SET 2 for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	3046	276	2300	0	0	0	0	0	0
2	3046	276	2400	0.13	65	65	0	0	0
3	3046	277	100	0.07	35	100	0.05448	0.437267	0.437267
4	3046	277	200	0.1	50	150	0.08951	0.718425	1.155693
5	3046	277	300	0.27	135	285	0.19069	1.530516	2.686209
6	3046	277	400	0.47	235	520	0.25296	2.030308	4.716516
7	3046	277	500	0.07	35	555	0.29966	2.405131	7.121647
8	3046	277	600	0.03	15	570	0.24128	1.936562	9.058209
9	3046	277	700	0.01	5	575	0.1868	1.499294	10.5575
10	3046	277	800	0	0	575	0.11675	0.937059	11.49456
11	3046	277	900	0	0	575	0.06616	0.531013	12.02558
12	3046	277	1000	0	0	575	0.06227	0.499791	12.52537
13	3046	277	1100	0.01	5	580	0.04281	0.343602	12.86897
14	3046	277	1200	0.13	65	645	0.05448	0.437267	13.30624
15	3046	277	1300	0	0	645	0.12842	1.030725	14.33696
16	3046	277	1400	0	0	645	0.08172	0.655901	14.99286
17	3046	277	1500	0.01	5	650	0.06227	0.499791	15.49265
18	3046	277	1600	0.03	15	665	0.05448	0.437267	15.92992
19	3046	277	1700	0	0	665	0.06616	0.531013	16.46093
20	3046	277	1800	0	0	665	0.04281	0.343602	16.80454
21	3046	277	1900	0	0	665	0.01557	0.124968	16.9295
22	3046	277	2000	0.03	15	680	0.01557	0.124968	17.05447
23	3046	277	2100	0.3	150	830	0.03113	0.249856	17.30433
24	3046	277	2200	0.38	190	1020	0.14399	1.155693	18.46002
25	3046	277	2300	0.3	150	1170	0.23739	1.90534	20.36536
26	3046	277	2400	0.5	250	1420	0.31912	2.561321	22.92668
27	3046	278	100	0.11	55	1475	0.36971	2.967366	25.89405
28	3046	278	200	0.08	40	1515	0.35414	2.842398	28.73644
29	3046	278	300	0.01	5	1520	0.31522	2.530019	31.26646
30	3046	278	400	0	0	1520	0.24128	1.936562	33.20302
31	3046	278	500	0	0	1520	0.17123	1.374326	34.57735
32	3046	278	600	0	0	1520	0.08951	0.718425	35.29578
33	3046	278	700	0	0	1520	0.05837	0.468489	35.76427
34	3046	278	800	0	0	1520	0.03502	0.281078	36.04534
35	3046	278	900	0	0	1520	0.01557	0.124968	36.17031
36	3046	278	1000	0	0	1520	0.01167	0.093666	36.26398
37	3046	278	1100	0	0	1520	0.01167	0.093666	36.35764
38	3046	278	1200	0	0	1520	0.00778	0.062444	36.42009
39	3046	278	1300	0	0	1520	0.00778	0.062444	36.48253
40	3046	278	1400	0	0	1520	0.00389	0.031222	36.51375
			CUMUL.	3.04			4.54543		
			VOLUME IN CFT	1520			36.48253		
			Outflow vol. as percentage of precip. volume				2.400166		

US-30, Laporte County (DATA SET 3 for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLOW cft
1	3046	298	500	0.01	5	5	0	0	0
2	3046	298	600	1.17	585	590	0.0467	0.37482354	0.37482354
3	3046	298	700	0.06	25	615	0.15177	1.21813637	1.59295991
4	3046	298	800	0.33	165	780	0.18291	1.46807224	3.06103216
6	3046	298	900	0.89	445	1225	0.22572	1.61167386	4.87270602
6	3046	298	1000	0	0	1225	0.26852	2.15519522	7.02790124
7	3046	298	1100	0.02	10	1235	0.2335	1.8741177	8.90201894
8	3046	298	1200	0.13	65	1300	0.20626	1.65548401	10.557503
9	3046	298	1300	0.09	45	1345	0.24128	1.93656154	12.4940645
10	3046	298	1400	0.02	10	1355	0.22961	1.84289578	14.3369603
11	3046	298	1500	0.06	30	1385	0.19069	1.53051608	15.8674764
12	3046	298	1600	0.04	20	1405	0.20626	1.65548401	17.5229604
13	3046	298	1700	0	0	1405	0.17902	1.43685032	18.9598107
14	3046	298	1800	0	0	1405	0.10507	0.84331283	19.8031235
15	3046	298	1900	0	0	1405	0.05837	0.46848929	20.2716128
16	3046	298	2000	0	0	1405	0.05448	0.43726738	20.7088802
17	3046	298	2100	0	0	1405	0.03892	0.3123797	21.0212599
16	3046	298	2200	0	0	1405	0.02335	0.18741177	21.2086717
19	3046	298	2300	0	0	1405	0.01557	0.12496793	21.3336396
20	3046	298	2400	0.17	85	1490	0.01557	0.12496793	21.4586075
21	3046	299	100	0.69	345	1835	0.1401	1.12447062	22.5830782
22	3046	299	200	0.03	15	1850	0.22961	1.84289578	24.4259739
23	3046	299	300	0	0	1850	0.22961	1.84289578	26.2688697
24	3046	299	400	0.01	5	1855	0.19458	1.551738	27.8306077
25	3046	299	500	0.04	20	1875	0.16734	1.34310431	29.173712
26	3046	299	600	0.01	5	1880	0.19847	1.59295991	30.7666719
27	3046	299	700	0.03	15	1895	0.18291	1.46807224	32.2347442
28	3046	299	800	0.02	10	1905	0.16734	1.34310431	33.5778485
28	3046	299	900	0.04	20	1925	0.16345	1.31188239	34.8897309
30	3046	299	1000	0.1	50	1975	0.19847	1.59295991	36.4826908
31	3046	299	1100	0.01	5	1980	0.21793	1.74914977	38.2318406
32	3046	299	1200	0	0	1980	0.20237	1.62426209	39.8561027
33	3046	299	1300	0	0	1980	0.16345	1.31188239	41.167985
34	3046	299	1400	0	0	1980	0.10897	0.87461501	42.0426001
35	3046	299	1500	0.01	5	1985	0.06227	0.49979147	42.5423915
35	3046	299	1600	0.01	5	1990	0.0467	0.37482354	42.9172151
37	3046	299	1700	0	0	1990	0.05448	0.43726736	43.3544824
38	3046	299	1800	0.01	5	1995	0.04281	0.34360162	43.6980841
39	3046	299	1900	0.22	110	2105	0.05837	0.46848929	44.1665734
40	3046	299	2000	0.13	65	2170	0.17902	1.43685032	45.6034237
41	3046	299	2100	0.03	15	2185	0.2335	1.8741177	47.4775414
42	3046	299	2200	0.01	5	2190	0.24128	1.93656154	49.4141029
43	3046	299	2300	0.03	15	2205	0.21015	1.68670593	51.1008089
44	3046	299	2400	0.13	65	2270	0.2335	1.8741177	52.9749266
45	3046	300	100	0.03	15	2285	0.26852	2.15519522	55.1301218
46	3046	300	200	0	0	2285	0.26074	2.09275139	57.2228732
47	3046	300	300	0.01	5	2290	0.23739	1.90533962	59.1282128
48	3046	300	400	0	0	2290	0.20626	1.65548401	60.7836968
49	3046	300	500	0	0	2290	0.17512	1.40554814	62.1892449
50	3046	300	600	0	0	2290	0.10897	0.87461501	63.06386
51	3046	300	700	0	0	2290	0.03113	0.24985561	63.3137156
52	3046	300	800	0	0	2290	0.0467	0.37482354	63.6885391
53	3046	300	900	0	0	2290	0.03892	0.3123797	64.0009188
54	3046	300	1000	0	0	2290	0.02335	0.18741177	64.1883306
55	3046	300	1100	0	0	2290	0.01557	0.12496793	64.3132985
56	3046	300	1200	0	0	2290	0.01557	0.12496793	64.4382664
57	3046	300	1300	0	0	2290	0.01167	0.09366575	64.5319322
58	3046	300	1400	0	0	2290	0.01167	0.09366575	64.6255979
59	3046	300	1500	0	0	2290	0.01167	0.09366575	64.7192637
60	3046	300	1600	0	0	2290	0.00778	0.06244384	64.7817075
61	3046	300	1700	0	0	2290	0.00778	0.06244384	64.8441514
62	3046	300	1800	0	0	2290	0.00389	0.03122192	64.8753733
63	3046	300	1900	0	0	2290	0.00778	0.06244384	64.9378171
64	3046	300	2000	0	0	2290	0.00389	0.03122192	64.969039
65	3046	300	2100	0	0	2290	0.00389	0.03122192	65.000261
65	3046	300	2200	0	0	2290	0.00389	0.03122192	65.0314829
67	3046	300	2300	0	0	2290	0.00389	0.03122192	65.0627048
		CUMUL		4.58			8.10629		
		VOLUME IN CFT		2290			65.0627048		
Outflow vol. as percentage of precip. volume							2.84116615		

US-30, Laporte County (DATA SET 4 for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	3046	301	1500	0.02	10	10	0	0	0
2	3046	301	1600	0.06	30	40	0.00389	0.031222	0.031222
3	3046	301	1700	0.02	10	50	0.03892	0.31238	0.343602
4	3046	301	1800	0.02	10	60	0.04281	0.343602	0.687203
5	3046	301	1900	0	0	60	0.03502	0.281078	0.968281
6	3046	301	2000	0	0	60	0.01167	0.093666	1.061947
7	3046	301	2100	0	0	60	0.01557	0.124968	1.186914
8	3046	301	2200	0	0	60	0.01167	0.093666	1.28058
9	3046	301	2300	0	0	60	0.00778	0.062444	1.343024
10	3046	301	2400	0	0	60	0.00778	0.062444	1.405468
11	3046	302	100	0	0	60	0.00389	0.031222	1.43669
12	3046	302	200	0	0	60	0.00389	0.031222	1.467912
13	3046	302	300	0	0	60	0.00389	0.031222	1.499134
14	3046	302	400	0.01	5	65	0.00389	0.031222	1.530356
15	3046	302	500	0	0	65	0.00389	0.031222	1.561577
16	3046	302	600	0	0	65	0.00389	0.031222	1.592799
17	3046	302	700	0.02	10	75	0.00389	0.031222	1.624021
18	3046	302	800	0	0	75	0.00389	0.031222	1.655243
19	3046	302	900	0	0	75	0.00389	0.031222	1.686465
			CUMUL.	0.15			0.20623		
		VOLUME IN CFT		75			1.655243		
	Outflow vol. as percentage of precip. volume						2.206991		

US-30, Laporte County (DATA SET 5 for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	3046	302	2000	0.06	30	30	0	0	0
2	3046	302	2100	0.05	25	55	0	0	0
3	3046	302	2200	0.45	225	280	0	0	0
4	3046	302	2300	0.21	105	385	0	0	0
5	3046	302	2400	0.09	45	430	0.03892	0.31238	0.31238
6	3046	303	100	0.41	205	635	0.22572	1.811674	2.124054
7	3046	303	200	0.06	30	665	0.26852	2.155195	4.279249
8	3046	303	300	0.1	50	715	0.28409	2.280163	6.559412
9	3046	303	400	0.07	35	750	0.29577	2.373909	8.933321
10	3046	303	500	0.05	25	775	0.27631	2.217719	11.15104
11	3046	303	600	0.07	35	810	0.28409	2.280163	13.4312
12	3046	303	700	0.06	30	840	0.26852	2.155195	15.5864
13	3046	303	800	0.08	40	880	0.26074	2.092751	17.67915
14	3046	303	900	0.05	25	905	0.25296	2.030308	19.70946
15	3046	303	1000	0.02	10	915	0.22572	1.811674	21.52113
16	3046	303	1100	0.05	25	940	0.19847	1.59296	23.11409
17	3046	303	1200	0.1	50	990	0.1868	1.499294	24.61339
18	3046	303	1300	0.06	30	1020	0.21404	1.717928	26.33131
19	3046	303	1400	0.02	10	1030	0.20626	1.655484	27.9868
20	3046	303	1500	0	0	1030	0.12064	0.968281	28.95508
21	3046	303	1600	0	0	1030	0.01167	0.093666	29.04874
			CUMUL.	2.06			3.61924		
			VOLUME IN CFT	1030			29.04874		
	Outflow vol. as percentage of precip. volume						2.820266		

US-31, St.Joseph County (DATA SET 1 for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	3171	220	600	0.05	46.85	46.85	0	0	0
2	3171	220	700	0.05	46.85	93.7	0.00753	0.060452	0.060452
3	3171	220	800	0.41	384.17	477.87	0.01129	0.090638	0.151091
4	3171	220	900	0.35	327.95	805.82	0.04518	0.362714	0.513805
5	3171	220	1000	0.64	599.68	1405.5	0.1393	1.118328	1.632133
6	3171	220	1100	0.37	346.69	1752.19	0.15436	1.239233	2.871366
7	3171	220	1200	0.08	74.96	1827.15	0.07153	0.574257	3.445623
8	3171	220	1300	0	0	1827.15	0.04518	0.362714	3.808337
9	3171	220	1400	0	0	1827.15	0.01882	0.151091	3.959428
10	3171	220	1500	0	0	1827.15	0.01129	0.090638	4.050066
11	3171	220	1600	0	0	1827.15	0.00753	0.060452	4.110519
12	3171	220	1700	0	0	1827.15	0.00753	0.060452	4.170971
13	3171	220	1800	0.02	18.74	1845.89	0.00376	0.030186	4.201157
14	3171	220	1900	0	0	1845.89	0.00753	0.060452	4.261609
15	3171	220	2000	0	0	1845.89	0.00376	0.030186	4.291795
16	3171	220	2100	0	0	1845.89	0.00376	0.030186	4.321981
17	3171	220	2200	0	0	1845.89	0.00376	0.030186	4.352168
18	3171	220	2300	0	0	1845.89	0	0	4.352168
			CUMUL.	1.97			0.54211		
		VOLUME IN CFT		1845.89			4.351083		
Outflow vol. as percentage of precip. volume							0.235717		

US-31, St.Joseph County (DATA SET 2 for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	3171	231	1000	0.06	56.22	56.22	0	0	0
2	3171	231	1100	0.07	65.59	121.81	0.01506	0.120875	0.120875
3	3171	231	1200	0	0	121.81	0.00376	0.030179	0.151053
4	3171	231	1300	0.17	159.29	281.1	0.03012	0.241749	0.392802
5	3171	231	1400	0.33	309.21	590.31	0.07906	0.634551	1.027354
6	3171	231	1500	0.08	74.96	665.27	0.11671	0.936738	1.964091
7	3171	231	1600	0.06	56.22	721.49	0.07906	0.634551	2.598643
8	3171	231	1700	0.05	46.85	768.34	0.07906	0.634551	3.233194
9	3171	231	1800	0	0	768.34	0.04894	0.392802	3.625996
10	3171	231	1900	0	0	768.34	0.01506	0.120875	3.746871
11	3171	231	2000	0	0	768.34	0.01129	0.090616	3.837487
12	3171	231	2100	0	0	768.34	0.00376	0.030179	3.867665
13	3171	231	2200	0	0	768.34	0.00376	0.030179	3.897844
14	3171	231	2300	0	0	768.34	0.00376	0.030179	3.928022
			CUMUL.	0.82			0.4894		
		VOLUME IN CFT		768.34			3.928022		
	Outflow vol. as percentage of precip. volume						0.511235		

US-31, St.Joseph County (DATA SET 3 for Rain and Flow)

TOT.HRS	RTE/CNTY	JULNDAY	TIME	RAIN INCHES	RAIN cft	CUM.RAIN cft	FLOW gpm	FLOW cft	CUM.FLO cft
1	3171	246	700	0.5	468.5	468.5	0.01129	0.090616	0.090616
2	3171	246	800	0.14	131.18	599.68	0.03012	0.241749	0.332365
3	3171	246	900	0.01	9.37	609.05	0.00753	0.060437	0.392802
4	3171	246	1000	0	0	609.05	0.00376	0.030179	0.422981
5	3171	246	1100	0	0	609.05	0.00376	0.030179	0.453159
6	3171	246	1200	0	0	609.05	0	0	0.453159
7	3171	246	1300	0	0	609.05	0	0	0.453159
8	3171	246	1400	0	0	609.05	0	0	0.453159
9	3171	246	1500	0	0	609.05	0	0	0.453159
10	3171	246	1600	0.28	262.36	871.41	0.01506	0.120875	0.574034
11	3171	246	1700	0.09	84.33	955.74	0.02259	0.181312	0.755346
12	3171	246	1800	0	0	955.74	0.00376	0.030179	0.785524
13	3171	246	1900	0.02	18.74	974.48	0.00753	0.060437	0.845961
14	3171	246	2000	0	0	974.48	0.00753	0.060437	0.906399
15	3171	246	2100	0	0	974.48	0.00376	0.030179	0.936577
16	3171	246	2200	0	0	974.48	0.00376	0.030179	0.966756
17	3171	246	2300	0	0	974.48	0.00376	0.030179	0.996934
			CUMUL.	1.04			0.12421		
		VOLUME IN CFT		974.48			0.996934		
	Outflow vol. as percentage of precip. volume						0.102304		

HOURLY DATA (US-31, Hamilton County)

TOT.HRS	RTE/CNT	TIME	RAIN [cm]	FLOW [cm3]	HEAD1 inner [cm]	HEAD2 center [cm]	HEAD3 outer [cm]	TENSION inner [cm]	TENSION center [cm]	TENSION outer [cm]	TEMP. subbase deg. 'F
1	3129	1600	0	1015.255	1.48529	1.052779	6.605626	8.906727	7.452892	9.329343	50.831
2	3129	1700	0	1015.255	1.697126	0.21336	7.000951	6.623929	7.314781	8.16104	51.302
3	3129	1800	0	1015.255	1.486205	0.610819	6.518148	6.486716	7.211348	9.044453	51.694
4	3129	1900	0	0	1.487119	0.425196	6.453835	6.432607	7.155745	8.985262	51.985
5	3129	2000	0	1015.255	1.465174	0.263652	6.347155	6.419454	7.174877	8.955368	52.101
6	3129	2100	0	0	1.489253	0.007315	6.209995	8.406301	7.199091	8.941019	52.163
7	3129	2200	0	0	1.466393	-0.22555	6.238342	6.411383	7.204771	8.936834	52.059
8	3129	2300	0	0	1.490777	-0.50505	6.125566	6.429618	7.232872	8.95208	51.859
9	3129	2400	0	0	1.514551	-0.78547	6.103315	6.434102	7.284887	8.967027	51.655
10	3129	100	0	0	1.491386	-0.99517	6.082284	6.438586	7.270538	8.987355	51.353
11	3129	200	0	0	1.467612	-1.25212	6.059119	6.471171	7.351551	9.018445	51.073
12	3129	300	0	0	1.515161	-1.60264	6.013399	6.502858	7.3943	9.043556	50.763
13	3129	400	0	0	1.515466	-2.06959	6.086246	6.534845	7.398784	9.058503	50.453
14	3129	500	0	0	1.515466	-2.35001	6.015533	6.539628	7.427482	9.088995	50.121
15	3129	600	0	0	1.515466	-2.81727	5.82869	6.585366	7.422699	8.104241	49.825
16	3129	700	0	0	1.350264	0.196901	6.039917	6.594633	7.498929	9.124569	49.53
17	3129	800	0	0	1.515466	0.313639	6.063082	6.617951	7.47053	9.145495	49.271
18	3129	900	0	0	1.51577	0.360578	6.204204	8.645453	7.541976	8.160143	48.975
19	3129	1000	0	0	1.515161	0.266395	6.526682	6.649937	7.59459	9.185553	48.765
20	3129	1100	0	0	1.491082	0.242621	6.337402	6.663091	7.617608	9.194521	48.557
21	3129	1200	0	0	1.490472	0.288646	6.216701	6.695376	7.58891	9.204685	48.412
22	3129	1300	0	0	1.489558	0.241097	6.211214	6.68581	7.607743	9.18914	48.484
23	3129	1400	0	0	1.488948	0.263957	6.255715	6.68581	7.60296	9.16373	48.637
24	3129	1500	0	0	1.511503	0.309372	6.270955	6.666977	7.640627	9.127259	48.893
25	3129	1600	0	0	1.605382	0.308762	6.385255	6.65771	7.578447	9.076439	49.201
26	3129	1700	0	0	1.605077	0.448666	6.618122	6.639175	7.626278	9.025619	49.586
27	3129	1800	0	0	1.534363	0.285598	6.431585	6.611673	7.5354	8.970315	49.947
28	3129	1900	0	0	1.535278	0.332842	6.342583	6.597922	7.52135	8.935339	50.236
29	3129	2400	0.1016	0	10.74207	27.95961	13.85011	6.047273	6.972195	7.909674	56.212
30	3129	100	0.1778	0	12.01583	28.73258	14.3192	6.029635	6.959042	7.895922	56.184
31	3129	200	0.2794	0	19.88729	28.94716	20.33565	6.047871	6.940209	7.87679	56.197
32	3129	300	0.1524	0	10.53602	28.13761	13.90985	6.133368	6.963526	8.061536	56.148
33	3129	400	0.0762	0	7.331659	28.51252	14.28415	6.16924	6.944992	8.164072	56.13
34	3129	500	0.2794	0	11.26785	28.16413	17.31569	6.232616	6.986843	8.267207	56.073
35	3129	600	0.1524	0	8.156753	28.14005	18.83024	6.300475	7.000894	8.321016	55.984
36	3129	700	0.0762	0	6.672986	27.74716	17.10903	6.377901	6.991627	8.39037	55.927
37	3129	800	0.0508	0	5.800954	27.74716	16.03644	6.451142	7.028994	8.434913	55.838
38	3129	900	0.0508	0	6.414516	27.42377	15.33997	6.515414	7.062177	8.474971	55.698
39	3129	1000	0	0	3.067507	25.93299	14.45666	6.607189	7.071444	8.514431	55.503
40	3129	1100	0	0	1.865376	24.76652	14.01409	6.639474	7.118676	8.559571	55.341
41	3129	1200	0	0	1.370381	23.71801	13.73581	6.718096	7.071743	8.584383	55.182
42	3129	1300	0	0	1.205179	22.94778	13.33927	6.764133	7.090576	8.594248	55.005
43	3129	1400	0	0	1.157935	22.10623	13.01161	6.814953	7.165311	8.588867	54.932
44	3129	1500	0	0	1.20457	21.21408	12.77264	6.860989	7.141695	8.568838	54.927
45	3129	1600	0	0	0.733044	19.86168	12.35385	6.907624	7.127645	8.543727	54.999
46	3129	1700	0	0	1.298753	19.37126	12.23681	6.907923	7.127944	8.529378	55.088
47	3129	1800	0	0	1.370076	18.34774	11.96096	6.954259	7.179361	8.529079	55.162
48	3129	1900	0	0	1.441094	17.46321	11.7537	6.978174	7.184742	8.539841	55.178
49	3129	2000	0	0	1.583131	16.76766	11.45621	7.010759	7.184443	8.549407	55.129
50	3129	2100	0	0	1.347826	15.6719	11.24803	7.067259	7.184742	8.579899	55.018
51	3129	2200	0	0	1.34813	14.78737	10.99505	7.086391	7.170991	8.615174	54.844
52	3129	2300	0	0	1.324966	13.99581	10.78809	7.133324	7.166208	8.65015	54.643
53	3129	2400	0	0	1.32527	13.27404	10.62807	7.184742	7.227192	8.694692	54.33
54	3129	100	0	0	1.349045	12.59738	10.41928	7.227491	7.24184	8.744914	53.993
55	3129	200	0	0	1.231697	12.0399	10.33059	7.24184	7.265456	8.785271	53.641
56	3129	300	0	0	1.137209	11.40958	10.19099	7.303422	7.256189	8.835792	53.257
57	3129	400	0	0	1.444142	10.82528	10.07364	7.322853	7.289969	8.886612	52.868
58	3129	500	0	0	1.349654	10.24128	9.910877	7.389218	7.351252	8.921887	52.482
59	3129	600	0	0	1.373429	9.727387	9.957206	7.441532	7.322853	8.962244	52.06
60	3129	700	0	0	1.326185	9.190025	9.863938	7.455882	7.394001	8.997519	51.694
61	3129	800	0	0	1.278941	8.629193	9.72373	7.541976	7.417916	9.023228	51.304
62	3129	1500	0	1015.255	1.133856	5.302301	8.507578	7.620897	7.468138	8.838781	50.702
63	3129	1600	0	87373.29	1.180795	4.998415	8.462584	7.621495	7.47322	8.763747	51.084
64	3129	1700	0	76198.66	1.251509	4.718609	8.273186	7.582931	7.430173	8.693496	51.519
65	3129	1800	0	69087.33	1.369466	4.532071	8.36737	7.573066	7.430173	8.638491	51.907
66	3129	1900	0	62991.26	1.370076	4.113581	8.277758	7.526133	7.392805	8.584682	52.191
67	3129	2000	0	57910.44	1.300277	3.741725	8.097012	7.540183	7.354541	8.564354	52.329
68	3129	2100	0	46735.81	1.324051	3.34579	7.983017	7.540482	7.345273	8.554788	52.332
69	3129	2200	0	45718.29	0.758647	2.57617	7.869326	7.564995	7.379054	8.560169	52.262
70	3129	2300	0	44703.03	1.324966	2.646883	7.754722	7.584127	7.40267	8.570333	52.069
71	3129	2400	0	42670.25	1.32527	2.46065	7.7343	7.603259	7.369488	8.58528	51.859
72	3129	100	0	39622.21	1.301801	2.15707	7.641336	7.617608	7.421802	8.60501	51.632
73	3129	200	0	37591.7	1.278026	1.900123	7.431024	7.641225	7.383538	8.62474	51.369
74	3129	300	0	33526.14	1.301801	1.596542	7.408164	7.660656	7.407453	8.649851	51.16

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75	3129	400	0	30478.1	1.278331	1.339901	7.315505	7.689653	7.440636	8.66988	50.899
76	3129	500	0	30478.1	1.254862	0.98999	7.340194	7.718949	7.446016	8.680343	50.635
77	3129	600	0	30478.1	1.231392	0.802843	7.27009	7.723135	7.474117	8.704856	50.461
78	3129	700	0	27432.34	1.254862	0.335585	7.199376	7.747648	7.488466	8.725184	50.201
79	3129	800	0	26414.81	1.254557	0.335585	7.128053	7.756915	7.459768	8.744615	50.009
80	3129	900	0	24384.3	1.207313	0.312115	7.128053	7.771264	7.545564	8.754779	49.833
81	3129	1000	0	23366.77	1.231087	0.335585	7.267956	7.795478	7.502815	8.770025	49.676
82	3129	1100	0	22351.52	1.230173	0.311201	7.215226	7.800261	7.526432	8.784972	49.521
83	3129	1200	0	22351.52	1.206094	0.287122	7.117994	7.79488	7.540183	8.779292	49.538
84	3129	1300	0	22351.52	1.157935	0.285902	7.064045	7.804446	7.544966	8.758964	49.602
85	3129	1400	0	23366.77	1.157326	0.262128	7.014667	7.770367	7.515969	8.728472	49.862
86	3129	1500	0	22351.52	1.204265	0.261823	7.059168	7.731206	7.501321	8.677951	50.248
87	3129	1600	0	21336.26	1.179578	0.260604	7.004914	7.702807	7.501619	8.618462	50.677
88	3129	1700	0	20318.73	1.485595	0.353873	6.9342	7.668727	7.463056	8.553293	51.149
89	3129	1800	0	12192.15	1.061618	-0.25268	7.120128	7.640328	7.401474	8.504267	51.624
90	3129	1900	0	11174.62	1.298143	0.331318	6.916217	7.606847	7.415823	8.449561	52.027
91	3129	2000	0	11174.62	1.251509	0.285598	6.85099	7.563799	7.373075	8.429831	52.309
92	3129	2100	0	10159.37	1.1811	0.262433	6.852514	7.568582	7.373075	8.415182	52.453
93	3129	2200	0	4063.293	1.205179	0.309372	6.785153	7.554831	7.364107	8.405915	52.519
94	3129	2300	0	0	1.535278	0.729691	7.416394	7.559315	7.368591	8.405317	52.54
95	3129	2400	0	0	1.18171	0.263042	6.670548	7.554233	7.316276	8.405317	52.491
96	3129	100	0	0	1.205179	0.286207	6.646164	7.568881	7.321358	8.405616	52.435
97	3129	200	0	0	0.710184	-0.11034	6.250229	7.573963	7.359623	8.410698	52.364
98	3129	300	0	0	1.205789	0.287122	6.534302	7.568881	7.330924	8.420563	52.28
99	3129	400	0	0	1.229563	0.263652	6.441034	7.568881	7.335707	8.430428	52.157
100	3129	500	0	1015.255	1.206094	0.310591	6.278575	7.588312	7.331223	8.435809	52.012
101	3129	600	0	0	1.229563	0.333756	6.208166	7.602661	7.34049	8.445375	51.891
102	3129	700	0	0	1.229563	0.287122	6.044489	7.612228	7.330924	8.460322	51.751
103	3129	800	0	0	1.229868	0.35753	6.023153	7.611929	7.368591	8.474971	51.558
104	3129	900	0	0	1.229868	0.334366	5.907634	7.631659	7.340789	8.480352	51.404
105	3129	1000	0	0	1.206398	0.310896	6.000902	7.640627	7.354541	8.484836	51.243
106	3129	1100	0	0	1.205789	0.287122	5.834177	7.645709	7.378456	8.499783	51.105
107	3129	1200	51.045	1015.255	1.1811	0.285902	5.757062	7.650492	7.373374	8.504566	
108	3129	1300	0	0	1.157021	0.285293	5.73024	7.635545	7.353943	8.484238	51.188
109	3129	1400	0	0	1.297534	0.284074	5.678119	7.611032	7.353644	8.454045	51.433
110	3129	1500	0	0	1.155802	0.283464	5.860999	7.596683	7.339295	8.409204	51.777
111	3129	1600	0	0	1.178966	0.259994	5.906414	7.548852	7.310895	8.36496	52.214
112	3129	1700	0	0	1.202436	0.283464	5.975909	7.524638	7.28698	8.315336	52.641
113	3129	1800	0	0	1.202741	0.259994	5.976518	7.481889	7.211647	8.26631	53.082
114	3129	1900	0	0	1.156106	0.284074	5.980786	7.477704	7.197896	8.237313	53.419
115	3129	2000	0	0	1.204265	0.331927	5.848198	7.472921	7.197896	8.207718	53.685
116	3129	2100	0	0	1.1811	0.332537	5.827166	7.439739	7.202679	8.203233	53.793
117	3129	2200	0	0	1.205179	0.356311	5.713781	7.425689	7.15156	8.193667	53.863
118	3129	2300	0	0	1.182319	0.357226	5.695188	7.449903	7.189525	8.208913	53.833
119	3129	2400	0	0	1.277112	0.404165	4.180942	7.44512	7.156343	8.213995	53.743
120	3129	100	0	0	1.206398	0.310896	5.534863	7.450202	7.175475	8.233725	53.602
121	3129	200	0	0	1.182929	0.311201	5.419649	7.459768	7.184742	8.24359	53.423
122	3129	300	0	0	1.13599	0.311201	5.233111	7.474117	7.147375	8.253455	53.226
123	3129	400	0	0	1.136294	0.31181	5.001768	7.483683	7.180258	8.268403	53.021
124	3129	500	0	0	1.11252	0.311506	5.163617	7.507598	7.180258	8.297998	52.767
125	3129	600	0	0	1.159459	0.311201	5.163312	7.521947	7.217925	8.312646	52.579
126	3129	700	0	0	1.159154	0.334366	5.04444	7.52135	7.203277	8.321913	52.437
127	3129	800	0	0	1.13538	0.334061	5.042916	7.530916	7.170393	8.321913	52.368
128	3129	900	0	0	1.13538	0.333756	4.995367	7.550048	7.231975	8.326995	52.293
129	3129	1000	0	0	1.111301	0.286817	4.85394	7.559614	7.293258	8.33686	52.243
130	3129	1100	0	0	1.086917	0.309372	4.895698	7.544966	7.217327	8.326397	52.274
131	3129	1400	0.0254	0	3.584143	0.308153	6.544361	7.425091	7.193113	8.276474	52.73
132	3129	1500	0	0	1.580998	0.261518	6.614465	7.406257	7.099245	8.242395	52.909
133	3129	1600	0	0	1.344778	0.914095	7.287463	7.316276	7.174578	8.222964	53.134
134	3129	1700	0	0	1.132942	0.261214	6.72907	7.358427	7.240345	8.193069	53.385
135	3129	1800	0	0	1.061923	0.260909	6.820205	7.32076	7.18833	8.173339	53.683
136	3129	1900	0	0	1.061923	0.284378	6.843674	7.325244	7.136613	8.148826	53.845
137	3129	2000	0	0	0.991514	0.214274	6.75071	7.373075	7.132129	8.134477	54.059
138	3129	2100	0	0	1.014679	0.260909	6.749491	7.377858	7.118078	8.109964	54.238
139	3129	2200	0	0	1.014679	0.260909	6.843065	7.301628	7.225996	8.104882	54.396
140	3129	2300	0	0	0.99121	0.284074	6.748272	7.292361	7.113295	8.105161	54.537
141	3129	2400	0	0	0.990905	0.260604	6.794297	7.315977	7.174279	8.090234	54.659
142	3129	100	0.0254	0	0.96713	0.23683	6.814718	7.277713	7.164414	8.070205	54.874
143	3129	200	1.0414	95502.14	26.26584	28.52044	23.40346	7.268745	7.132129	7.645111	55.21
144	3129	300	0	427724.6	5.254142	27.07356	10.91489	7.140798	7.107914	8.011612	55.352
145	3129	400	0.254	540492.9	12.86256	28.44973	17.50832	7.18833	7.13183	7.963483	55.572
146	3129	500	0.5588	961108.4	16.84386	28.07757	20.841	7.178763	7.052013	7.909973	55.691
147	3129	600	0.3048	1016981	14.27744	28.59298	21.02998	7.127047	7.080113	7.934167	55.838
148	3129	700	0.2032	1023091	10.34339	27.75356	16.8594	7.268745	7.071145	7.939269	55.946
149	3129	800	0.127	1020048	8.835847	27.21773	15.46159	7.207462	7.03856	7.939566	55.998
150	3129	900	0	896082.1	3.959047	27.28631	14.78463	7.169795	7.136912	7.97843	56.107
151	3129	1000	0.381	861536.1	27.11653	28.54635	23.31354	7.315678	6.977277	7.895623	56.196
152	3129	1100	0.1016	1011917	10.814	27.26284	15.60027	7.183845	7.122563	7.929703	56.287
153	3129	1200	0.1016	910322.9	12.22675	27.56428	16.99626	7.301628	6.976978	7.900107	56.479
154	3129	1300	0.0254	885929.5	5.701589	27.07386	14.68892	7.310895	6.981761	7.900107	56.662
155	3129	1400	0	787379.3	3.817315	26.88763	14.27013	7.193113	7.009862	7.914756	56.663

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156	3129	1500	0	705091.4	2.521915	25.76932	13.805	7.268446	7.131531	7.885758	56.915
157	3129	1600	0	664458.5	2.02692	24.64857	13.52398	7.348562	6.953362	7.860946	57.084
158	3129	1700	0	644130.7	1.579169	23.6665	13.21826	7.192515	7.079515	7.870512	57.243
159	3129	1800	0	627868.4	1.484681	22.89475	13.02959	7.296546	6.925561	7.841814	57.438
160	3129	1900	0	594344.5	1.343558	22.19889	12.73028	7.244231	7.089081	7.846298	57.709
161	3129	2000	0	559798.6	1.48529	21.38477	12.61598	7.291763	6.948878	7.832248	57.891
162	3129	2100	0	543536.4	1.24968	20.52249	12.38341	7.225697	7.03288	7.841814	58.021
163	3129	2200	0	517121.5	1.014374	19.73001	12.10422	7.253798	6.916293	7.841814	58.074
164	3129	2300	0	495794.4	0.96713	18.91375	11.87105	7.188031	6.930344	7.856462	58.199
165	3129	2400	0.127	480554.2	11.07277	28.89413	17.09014	7.211647	6.911809	7.837031	58.277
166	3129	100	0.5842	740636.7	27.46766	28.80025	23.8695	7.168197	6.869659	7.78382	58.277
167	3129	200	0.5334	994632.2	29.23276	28.72923	29.66923	7.131531	6.897759	7.808034	58.37
168	3129	300	0.6604	1030200	29.24068	28.94716	29.35376	7.141396	6.944693	7.837629	58.391
169	3129	400	0.762	1070833	29.50464	28.9752	29.31353	7.240345	6.907325	7.861843	58.333
170	3129	500	0.127	1003785	14.07201	27.50942	16.12575	7.259477	6.926158	7.862142	58.241
171	3129	600	0	916409.9	6.931457	26.81112	14.70508	7.221512	6.95396	7.905488	58.043
172	3129	700	0	741658.8	4.339742	24.99482	13.98575	7.302226	6.935725	7.954216	57.901
173	3129	800	0	644130.7	3.42138	23.60097	13.47917	7.302525	7.024809	8.013107	57.669
174	3129	900	0	601453.6	3.186989	22.58111	13.20637	7.307308	6.968907	8.106078	57.412
175	3129	1000	0	570973.2	2.975458	21.44116	12.86073	7.417019	7.011357	8.17035	57.194
176	3129	1100	0	548624	2.692908	20.2058	12.55989	7.379054	6.889987	8.258537	56.761
177	3129	1200	0	505946.9	2.457907	19.04238	12.30782	7.421802	6.946188	8.322511	56.436
178	3129	1300	0	492750.9	2.127504	17.75826	11.88811	7.450202	7.185041	8.391566	56.081
179	3129	1400	0	459227	1.891589	16.59087	11.63208	7.38862	7.147375	8.451055	55.688
180	3129	1500	0	434833.6	1.797406	15.54114	11.33033	7.40267	7.100441	8.505463	55.222
181	3129	1600	0	409440.9	1.561795	14.35059	11.0048	7.407453	7.133324	8.560169	54.886
182	3129	1700	0	393178.6	1.420368	13.32403	10.74969	7.531514	7.063073	8.610391	54.563
183	3129	1800	0	369807.3	1.278941	12.50777	10.4016	7.641823	7.063073	8.65015	54.164
184	3129	1900	0	338327.6	1.043026	11.64306	10.28395	7.603857	7.204472	8.705753	53.749
185	3129	2000	0	321043.3	0.972007	11.19896	10.6107	7.560212	7.12884	8.76016	53.413
186	3129	2100	0	300738.2	0.688848	10.24098	10.0267	7.622989	7.214038	8.785869	53.118
187	3129	2200	0	274323.4	0.618439	9.611868	9.98281	7.695034	7.256488	8.780787	52.638
188	3129	2300	0	248907.9	0.547726	8.958986	9.938614	7.699817	7.312988	8.845956	52.273
189	3129	2400	0	230624.2	0.406298	8.304886	9.775546	7.743761	7.332718	8.912321	51.799
190	3129	100	0	205226.9	0.264566	7.914462	9.683191	7.830155	7.327636	8.941916	51.399
191	3129	200	0	191004.3	0.123139	7.278319	9.545422	7.805941	7.394001	9.002601	50.976
192	3129	300	0	156460.6	0.477317	6.740652	9.358274	7.844505	7.388919	9.032495	50.472
193	3129	400	0	141220.4	1.04394	6.203594	9.219286	7.888449	7.427482	9.088995	50.092
194	3129	500	0	132076.3	1.02047	5.712866	9.032443	7.888449	7.432265	9.109323	49.723
195	3129	600	0	121916.9	0.997306	5.270297	8.873338	7.966173	7.570675	9.134434	49.307
196	3129	700	0	110742.3	0.950062	4.896307	8.639556	8.029848	7.489662	9.114405	48.908
197	3129	800	0	99565.43	0.973836	4.452518	8.384134	7.976038	7.53241	9.124569	48.577
198	3129	900	0	90421.32	0.78486	4.288536	7.986065	7.951824	7.685767	9.124569	48.184
199	3129	1000	0	80261.95	0.902513	3.563417	8.240878	8.141951	7.518061	9.114405	47.805
200	3129	1100	0	70102.58	0.854659	2.954426	7.90895	8.08276	7.709383	9.154463	47.562
201	3129	1200	0	61973.73	0.901294	2.625852	7.833665	8.146136	7.617907	9.144598	47.332
202	3129	1300	0	54862.4	0.877214	2.227478	7.66572	8.150321	7.646008	9.06209	47.243
203	3129	1400	0	50799.11	0.900379	1.969618	7.637678	8.140755	7.646307	9.031897	47.36
204	3129	1500	0	46735.81	0.970483	1.758696	7.471258	8.145837	7.627175	8.99154	47.598
205	3129	1600	0	42670.25	0.89977	1.431646	7.353605	8.100996	7.717754	8.96045	47.945

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TOT.HRS	RTE/CNT	TIME	RAIN [cm]	FLOW [cm3]	HEAD1 inner [cm]	HEAD2 center [cm]	HEAD3 outer [cm]	HEAD4 subgrade [cm]	TENSION center [cm]	TENSION outer [cm]	TENSION subgrade [cm]	TEMP subbase deg. F
1	3129	100	0	1539.917	-4.84967	0.258775	47.60671	-0.04511	5.078882	5.001768	5.230063	88.155
2	3129	200	0	1539.917	-4.89722	0.25908	47.49698	-0.1143	5.08315	5.018837	5.24317	87.87
3	3129	300	0	1539.917	-4.89753	0.21275	47.40859	-0.06736	5.088026	5.023409	5.239207	87.441
4	3129	400	0	3079.835	-4.89783	0.25969	47.22876	-0.06675	5.105096	5.03621	5.238902	87.143
5	3129	500	0	3079.835	-4.96854	0.283159	46.76546	-0.37003	5.113934	5.04505	5.247742	86.767
6	3129	600	0	1539.917	-4.89814	0.21336	46.90872	-0.08931	5.127041	5.049317	5.248046	86.256
7	3129	700	0	0	-4.89814	0.23683	46.72584	-0.11247	5.131308	5.062423	5.256581	85.883
8	3129	800	0	3079.835	-4.89814	0.143256	46.74413	-0.11278	5.126736	5.066386	5.247742	85.43
9	3129	900	0	3079.835	-4.89661	0.165202	46.7868	-0.11552	5.126126	5.061509	5.242865	85.036
10	3129	1000	0	6159.67	-4.91856	0.187147	46.92091	-0.07132	5.126431	5.057546	5.230063	84.863
11	3129	1100	0	6929.629	-4.87009	0.162154	46.89348	-0.09754	5.10479	5.04444	5.247437	84.833
12	3129	1200	0	12319.34	-4.89265	0.161544	46.80814	-0.09906	5.082845	5.022799	5.255666	84.96
13	3129	1300	0	16939.09	-4.89265	0.231038	46.59782	-0.09936	5.061204	4.996891	5.24256	85.49
14	3129	1400	0	16939.09	-4.91642	0.208178	46.43933	-0.09845	5.009998	4.967021	5.255971	86.14
15	3129	1500	0	16939.09	-4.96397	0.418186	46.44847	-0.0509	4.992929	4.924654	5.230063	86.93
16	3129	1600	0	16169.13	-4.91734	0.278892	46.78375	-0.07346	4.941722	4.894783	5.24317	87.914
17	3129	1700	0	15399.17	-5.12917	0.162458	47.43298	-0.14356	4.941722	4.873447	5.208422	88.793
18	3129	1800	0	16169.13	-4.91795	0.349301	48.11878	-0.04938	4.903318	4.860646	5.221529	89.469
19	3129	1900	0	14629.22	-4.91795	0.349606	48.40224	-0.04907	4.903318	4.856378	5.208422	89.931
20	3129	2000	0	14629.22	-4.94203	0.350215	48.36566	-0.04816	4.907585	4.856378	5.186782	90.228
21	3129	2100	0	13859.26	-4.94233	0.326746	48.27422	-0.04785	4.911547	4.851806	5.18221	90.356
22	3129	2200	0	13859.26	-5.24927	0.420929	48.40529	0.117043	4.920082	4.860341	5.173675	90.395
23	3129	2300	0	11549.38	-4.96672	0.28133	48.0822	-0.06949	4.932578	4.864303	5.169103	90.258
24	3129	2400	0	11549.38	-4.99049	0.28133	47.89932	-0.09266	4.941418	4.881677	5.160874	90.047
25	3129	100	0	10009.46	-4.9914	0.23561	47.74997	-0.1146	4.94599	4.894783	5.169713	89.682
26	3129	200	0	8469.546	-4.9914	0.25908	47.66158	-0.09083	4.96763	4.903318	5.165446	89.297
27	3129	300	0	6929.629	-4.99201	0.23622	47.60062	-0.11339	4.971898	4.916424	5.170018	88.874
29	3129	400	0	6159.67	-4.99232	0.213055	47.48784	-0.11308	4.989271	4.929226	5.161483	88.432
29	3129	500	0	3849.794	-5.03926	0.21336	47.3964	-0.15972	4.997806	4.93776	5.178552	87.986
30	3129	600	0	3079.835	-5.03956	0.23683	47.28362	-0.13594	5.015179	4.946599	5.170018	87.607
31	3129	700	0	2309.876	-5.03956	0.166726	46.98187	-0.13594	5.027981	4.959401	5.170018	87.102
32	3129	800	0	2309.876	-5.03956	0.120091	46.63135	-0.13594	5.023714	4.963668	5.183124	86.689
33	3129	900	0	3079.835	-5.01548	0.166421	46.62221	-0.18349	5.031638	4.963058	5.169713	86.232
34	3129	1000	0	4619.752	-4.99049	0.188062	46.59478	-0.18623	5.009998	4.962754	5.177942	85.901
35	3129	1100	0	4619.752	-4.98897	0.163373	46.56734	-0.18867	5.01457	4.954524	5.165141	85.759
36	3129	1200	0	1539.917	-4.98775	0.185623	46.52162	-0.1207	4.988662	4.933188	5.169713	85.883
37	3129	1300	0	769.9587	-4.98744	0.255118	46.42409	-0.12131	4.945685	4.90728	5.18221	86.245
38	3129	1400	0	0	-4.98714	0.278282	46.30217	-0.12192	4.90728	4.87741	5.177942	86.905
39	3129	1500	0	0	-4.98775	0.301752	46.49724	-0.09754	4.881982	4.852111	5.165141	87.792
40	3129	1600	0	769.9587	-5.24622	0.115519	46.96054	-0.12101	4.852111	4.813706	5.182514	88.758
41	3129	1700	0	0	-4.98775	0.348691	47.61586	-0.09754	4.817974	4.779569	5.169713	89.706
42	3129	1800	0	0	-5.03499	0.348691	48.10658	-0.09723	4.813706	4.758538	5.134966	90.485
43	3129	1900	0	0	-4.98805	0.372161	48.20412	-0.09693	4.79237	4.750003	5.130698	91.152
44	3129	2000	0	0	-4.98805	0.348996	48.08525	-0.1204	4.779569	4.745736	5.130698	91.648
45	3129	2100	0	0	-4.98836	0.349301	48.02124	-0.09632	4.796638	4.745736	5.10479	91.911
46	3129	2200	0	0	-5.01244	0.326441	48.00905	-0.11887	4.800905	4.75427	5.109362	91.968
47	3129	2300	0	0	-4.98927	0.326746	47.87798	-0.14143	4.817974	4.762805	5.100523	91.899
48	3129	2400	0	0	-4.99019	0.32766	47.84446	-0.18684	4.834738	4.779264	5.095951	91.662
49	3129	100	0	769.9587	-4.99019	0.304495	47.7073	-0.18654	4.830166	4.783531	5.106753	91.396
50	3129	200	0	0	-4.99049	0.32827	47.62195	-0.16246	4.847539	4.787798	5.091684	91.074
51	3129	300	0	0	-4.99049	0.3048	47.50613	-0.2094	4.851806	4.79237	5.067417	90.647
52	3129	400	0	0	-4.9911	0.30541	47.44517	-0.18501	4.86918	4.805172	5.091989	90.252
53	3129	500	0	0	-4.9914	0.28255	47.31106	-0.20787	4.877714	4.817974	5.091989	89.807
54	3129	600	0	0	-4.99171	0.259385	47.244	-0.20757	4.881982	4.822241	5.105095	89.372
55	3129	700	0	0	-5.06242	0.282854	47.13427	-0.23043	4.899355	4.835347	5.100828	88.903
56	3129	800	0	0	-4.99171	0.329489	46.92396	-0.23043	4.907585	4.835042	5.096256	88.476
57	3129	900	0	0	-5.01457	0.25847	46.67402	-0.20848	4.903013	4.839005	5.100218	88.064
58	3129	1000	0	0	-4.94294	0.281026	46.58563	-0.21031	4.894478	4.839005	5.104486	87.707
59	3129	1100	0	0	-4.98866	0.256337	46.51248	-0.23592	4.89905	4.830775	5.100523	87.618
60	3129	1200	0	0	-4.72867	1.76845	46.02785	-0.72786	4.873447	4.826508	5.117897	87.705
61	3129	1300	0	0	-4.98683	0.301142	46.29912	-0.09876	4.864608	4.809439	5.113325	88.077
62	3129	1400	0	0	-4.98714	0.301447	46.30217	-0.21519	4.843272	4.787798	5.117287	88.616
63	3129	1500	0	0	-5.0103	0.301142	46.46066	-0.14539	4.817669	4.771034	5.113325	89.261
64	3129	1600	0	0	-4.98744	0.324917	46.77156	-0.16825	4.775302	4.737202	5.126431	90.097
65	3129	1700	0	0	-4.98744	0.371551	47.07636	-0.14448	4.775302	4.720133	5.100523	90.963
66	3129	1800	0	0	-4.91703	0.395021	47.42688	-0.14448	4.741469	4.699102	5.109058	91.775
67	3129	1900	0	0	-4.98744	0.371551	47.56709	-0.12101	4.728667	4.690567	5.109058	92.468
68	3129	2000	0	0	-5.03499	0.325526	47.55185	-0.1902	4.728667	4.686605	5.091989	92.88
69	3129	2100	0	0	-5.01152	0.325526	47.52746	-0.21336	4.732934	4.690567	5.067722	93.1
70	3129	2200	0	0	-4.98836	0.325831	47.46346	-0.23652	4.737202	4.694834	5.074615	93.225
71	3129	2300	0	0	-5.01244	0.302971	47.4025	-0.25908	4.766767	4.699102	5.052974	93.125
72	3129	2400	0	0	-5.03652	0.32705	47.34456	-0.23439	4.762805	4.703369	5.061614	92.57
73	3129	2100	0.6096	0	2.563063	8.568538	47.34154	10.37966	4.707636	4.669536	5.035906	92.677
74	3129	2200	0.2032	20018.93	-1.69469	0.465734	46.74413	1.63066	4.674106	5.162619	5.044745	92.774

HOURLY DATA (SR-37, Lawrence County)

TOT.HRS	RTE/CNTY	TIME	RAIN [cm]	HEAD1 inner [cm]	HEAD2 center [cm]	HEAD4 subgrade [cm]	TENSION center [cm]	TENSION outer [cm]	TENSION subgrade [cm]	TEMP subbase deg. °F
1	3747	1300	0.127	0	0	0	1.863852	1.8492216	1.915668	0
2	3747	1400	0.2286	0	0	0	1.8492216	1.8342864	1.915668	0
3	3747	1500	0	0	2.980944	5.83692	1.9860768	1.8934176	1.9488912	0
4	3747	1600	0	-0.283769	7.8065376	11.350142	6.8918328	7.0506336	6.367272	80.909
5	3747	1700	0.0762	-0.612953	8.1323688	11.326063	6.9055488	7.0878192	6.4218312	81.407
6	3747	1800	0	-0.824789	8.3884008	11.372393	6.9287136	7.1253096	6.4581024	81.478
7	3747	1900	0	-1.083869	8.5048344	11.395558	6.9424296	7.1484744	6.4806576	81.532
8	3747	2000	0	-1.295705	8.5746336	11.395253	6.9610224	7.1624952	6.5126616	81.578
9	3747	2100	0	-1.554785	8.2716624	11.442192	6.9564504	7.171944	6.5495424	81.599
10	3747	2200	0	-1.766621	8.2253328	11.465966	6.966204	7.1722488	6.5681352	81.532
11	3747	2300	0	-2.167433	8.1558384	11.512906	6.9756528	7.1725536	6.595872	81.46
12	3747	2400	0	-2.450287	8.2030824	11.536985	6.9759576	7.1774304	6.600444	81.296
13	3747	100	0	-1.744066	8.0168496	11.584229	6.9805296	7.1728584	6.6190368	81.151
14	3747	200	0	-1.744066	7.99338	11.583924	6.9759576	7.1634096	6.6144648	80.955
15	3747	300	0	-1.744066	7.9702152	11.607394	6.9765672	7.1545704	6.6196464	80.81
16	3747	400	0	-1.767535	7.8537816	11.654333	6.9948552	7.1402448	6.6239136	80.544
17	3747	500	0	-1.79131	7.7370432	11.700967	6.9762624	7.1542656	6.6284856	80.354
18	3747	600	0	-1.79131	7.6907136	11.724437	6.9811392	7.1311008	6.6287904	80.12
19	3747	700	0	-1.814779	7.5739752	11.724437	6.9671184	7.1265288	6.6519552	79.853
20	3747	800	0	-1.838249	7.4106024	11.724132	6.9625464	7.11708	6.6101976	79.649
21	3747	900	0	-2.851099	6.6412872	11.794236	6.9527928	7.1118984	6.6193416	79.448
22	3747	1000	0	-1.884883	6.990588	11.746687	6.9384672	7.0975728	6.586728	79.344
23	3747	1100	0	-1.860194	6.9424296	11.791493	6.9195696	7.0878192	6.5864232	79.346
24	3747	1200	0	-1.882445	6.9643752	11.766194	6.9012816	7.0695312	6.573012	79.688
25	3747	1300	0	-1.92786	6.8927472	11.810086	6.864096	7.027164	6.559296	80.301
26	3747	1400	0	-1.950415	7.0082664	11.855196	6.8311776	6.9802248	6.5403984	81.174
27	3747	1500	0	-1.97358	7.1240904	11.831117	6.8080128	6.9290184	6.5315592	82.318
28	3747	1600	0	-1.878787	7.6818744	11.830202	6.7385184	6.9055488	6.5266824	83.68
59	3747	2400	0.0254	7.7196696	33.384744	12.233453	6.3172848	6.3447168	6.3310008	88.148
60	3747	100	0.0254	23.326039	32.385	13.004597	6.1990224	6.2624208	6.2715648	87.907
61	3747	200	0	23.208082	32.128968	13.54135	6.1536072	6.27126	6.2349888	87.539
62	3747	300	0	24.622354	32.595312	13.378586	6.144768	6.298692	6.2170056	87.12
63	3747	400	0.0508	24.435511	32.482536	14.289938	6.144768	6.3303912	6.1990224	86.491
64	3747	500	0	23.896015	31.879032	13.566648	6.1490352	6.3575184	6.1853064	86.038
65	3747	600	0	23.473562	31.366968	12.492838	6.158484	6.3898272	6.1718952	85.599
66	3747	700	0	23.096525	30.644592	12.189257	6.1673232	6.4306704	6.1581792	85.145
67	3747	800	0	22.884994	29.689958	12.602414	6.1761624	6.4715136	6.1536072	84.81
68	3747	900	0	25.239878	32.650176	12.189257	6.1853064	6.5218056	6.1444632	84.422
69	3747	1000	0	23.921009	31.601664	12.305995	6.1990224	6.5724024	6.1359288	84.112
70	3747	1100	0	24.48306	32.366712	12.165178	6.2307216	6.6138552	6.1313568	83.935
71	3747	1200	0	23.680826	31.781496	14.59291	6.2127384	6.6601848	6.1405008	83.655
72	3747	1300	0	23.936858	31.473648	14.428318	6.2218824	6.6879216	6.1228224	83.668
73	3747	1400	0	23.135539	30.448301	14.311274	6.2313312	6.7113912	6.1408056	83.812
74	3747	1500	0	22.901758	29.378453	14.358518	6.2307216	6.7385184	6.1313568	84.067
75	3747	1600	0	22.574402	28.169616	14.779752	6.2352936	6.7616832	6.153912	84.115
76	3747	1700	0	22.38817	27.379879	15.107412	6.2349888	6.7845432	6.1267848	84.137
77	3747	1800	0	22.154998	26.450239	15.038527	6.2352936	6.793992	6.1359288	84.059
78	3747	1900	0	21.897746	25.403251	14.82913	6.2441328	6.8171568	6.1267848	84.009
79	3747	2000	0	21.662746	24.424843	14.361871	6.2490096	6.8406264	6.1270896	83.912
80	3747	2100	0	21.474379	23.608894	13.637971	6.2487048	6.8543424	6.1313568	83.711
81	3747	2200	0	21.192744	22.631095	12.167006	6.2855856	6.868668	6.1228224	83.488
82	3747	2300	0	20.936407	21.747785	11.396777	6.2672976	6.9153024	6.1136784	83.183
83	3747	2400	0	20.72579	20.88642	10.532669	6.2767464	6.9247512	6.1228224	82.885
84	3747	100	0	20.51365	20.117105	9.73836	6.2816232	6.9530976	6.1231272	82.508
85	3747	200	0	20.750479	19.861682	9.294876	6.2950344	6.986016	6.1054485	82.116
86	3747	300	0	20.045172	18.603773	8.6173056	6.3087504	7.0235064	6.11886	81.649

HOURLY DATA (US-41, Sullivan County)

TOT.HRS	RTE/CNT	TIME	RAIN [cm]	FLOW [cm3]	HEAD2 center [cm]	HEAD3 outer [cm]	TENSION center [cm]	TENSION outer [cm]	TENSION subgrade [cm]	TEMP. subbase deg. 'F
1	4177	1400	0	0	0.893064	4.11541	6.537237	8.100697	5.589295	93.183
2	4177	1500	0	0	0.868985	4.112362	6.474459	8.0433	5.572256	101.33
3	4177	1600	0	0	0.84521	4.109923	6.425433	7.981718	5.572555	105.01
4	4177	1700	0	0	0.821741	4.109009	6.385375	7.929404	5.572854	104.15
5	4177	1800	0	0	0.891235	4.085844	6.344719	7.87679	5.60783	97.045
6	4177	1900	0	0	0.961339	4.018483	6.344121	7.856761	5.62457	90.095
7	4177	2000	0	0	0.938784	3.973678	6.334555	7.846896	5.628457	84.049
8	4177	2100	0	924.4047	0.939698	3.837432	6.374912	7.86543	5.623973	80.44
9	4177	2200	0	0	0.917143	3.816401	6.365944	7.870512	5.619488	86.572
10	4177	2300	0	0	0.940918	3.655162	6.388663	7.894428	5.628457	39.991
11	4177	2400	0	0	0.941222	3.376574	6.424237	7.922528	5.641311	39.402
12	4177	100	0	0	0.941832	3.122066	6.43739	7.946144	5.632343	38.991
13	4177	200	0	0	0.918972	2.959913	6.486716	7.988893	5.649383	38.595
14	4177	300	0	0	0.895807	2.657246	6.486417	8.012509	5.671205	38.227
15	4177	400	0	0	0.919277	2.098243	6.509136	8.051073	5.679576	37.884
16	4177	500	0	0	0.942442	1.515466	6.553977	8.09412	5.697213	37.487
17	4177	600	0	0	0.919277	0.839724	6.594932	8.137466	5.723221	37.224
18	4177	700	0	0	0.919277	0.140513	6.635887	8.190678	5.749528	36.927
19	4177	800	0	0	0.919277	-0.90861	6.640371	8.219675	5.684359	36.615
20	4177	800	0	0	0.919277	1.562405	6.662792	8.243889	5.732189	36.301
21	4177	1000	0	0	0.896112	1.492606	6.676543	8.263022	5.736374	36.119
22	4177	1100	0	0	0.849478	1.491996	6.658308	8.268104	5.701697	48.937
23	4177	1200	0	0	0.917753	1.535582	6.668472	8.288432	5.715448	75.531
24	4177	1300	0	0	0.824179	1.463345	6.6323	8.260331	5.676586	76.231
25	4177	1400	0	0	0.823265	1.414577	6.58716	8.211604	5.658949	82.383
26	4177	1500	0	0	0.84582	1.436218	6.528866	8.149424	5.62457	85.116
27	4177	1600	0	0	0.86868	1.435913	6.479242	8.086945	5.615901	85.413
28	4177	1700	0	0	0.984504	1.574902	6.438586	8.038816	5.615901	84.368
29	4177	1800	0	0	0.984504	1.505712	6.416166	7.990985	5.611716	80.836
30	4177	1900	0	0	0.915314	1.506322	6.406898	7.966472	5.632941	77.612
31	4177	2000	0	0	0.985723	1.50815	6.397332	7.956607	5.64161	74.932
32	4177	1900	0.0254	0	0.939394	1.507846	6.442771	7.923425	5.598264	65.296
33	4177	2000	0	0	0.939394	1.508455	6.415867	7.903994	5.58511	64.725
34	4177	2100	0	0	0.939698	1.555394	6.392848	7.903695	5.588996	63.915
35	4177	2200	0	0	0.916534	1.53223	6.379396	7.903695	5.59378	63.278
36	4177	2300	0	0	0.916534	1.532534	6.374912	7.898912	5.593481	62.885
37	4177	2400	0	0	0.916534	1.4859	6.379396	7.908478	5.597666	62.534
38	4177	100	0	0	0.939698	1.50937	6.379097	7.917745	5.632343	62.074
39	4177	200	0	0	0.893369	1.486205	6.384179	7.92761	5.628457	61.705
40	4177	300	0	0	0.916534	1.50937	6.388663	7.927909	5.628457	61.435
41	4177	400	0	0	0.916838	1.509979	6.388663	7.932692	5.624271	61.1
42	4177	500	0	0	0.893674	1.48651	6.397332	7.941959	5.623973	60.645
1	4177	600	0	0	0.940308	1.533754	6.406301	7.951525	5.628457	60.481
2	4177	700	0	0	0.893674	1.510284	6.411084	7.966472	5.628756	60.084
3	4177	800	0	0	0.940308	1.533754	6.420351	7.976038	5.624271	59.991
4	4177	900	0	0	0.893978	1.510589	6.433803	7.985903	5.628756	59.753
5	4177	1000	0	0	0.917143	1.510894	6.442173	7.999356	5.628457	59.525
6	4177	1100	0	0	0.893978	1.510894	6.447255	8.00952	5.628457	59.468
7	4177	300	0.2794	45258.49	5.949391	12.5669	6.447255	8.00952	5.624271	59.575
8	4177	400	0.1778	306643.4	5.184038	10.98347	6.455925	8.014004	5.628457	59.702
9	4177	500	0.1016	311276.8	4.511345	10.37783	6.460409	8.018787	5.632642	59.737
10	4177	600	0.0254	385181.1	3.90845	10.35558	6.456224	8.014004	5.632941	59.755
11	4177	700	0.0762	413801.7	4.326026	10.4714	6.455925	8.009221	5.632642	59.771
12	4177	800	0	318658.4	3.815486	10.07547	6.460409	8.008922	5.645795	59.701
13	4177	900	0.0508	55418.86	4.48818	10.12241	6.456224	7.999655	5.637425	59.37
14	4177	1000	0.0508	174569.4	4.882591	10.75121	6.438287	7.718352	5.641909	56.014
15	4177	1100	0.127	460907.7	4.697273	10.54181	6.433504	7.718053	5.59378	55.891
16	4177	1200	0.1778	325131.5	5.091074	10.63417	6.406599	7.699518	5.567772	55.747
17	4177	1300	0.0254	393473.9	4.255618	10.07394	6.424536	7.703703	5.567772	55.451
18	4177	1400	0	105295.8	3.953866	9.956902	6.446956	7.72732	5.576441	55.167
19	4177	1500	0.0254	0	3.907231	10.14283	6.437988	7.727619	5.571957	54.873
20	4177	1600	0.0762	187499.7	4.950562	10.84052	6.451441	7.732402	5.567473	54.611
21	4177	1700	0.1778	274323.4	6.828739	11.21237	6.442472	7.727619	5.558803	54.346
22	4177	1800	0.1778	280796.5	4.64881	10.39764	6.460409	7.746751	5.558803	54.19
23	4177	1900	0.127	287422.1	4.672279	10.49152	6.465192	7.746751	5.550433	54.203
24	4177	2000	0.0508	299261.8	4.347667	10.53785	6.465192	7.737484	5.541764	54.238
25	4177	2100	0.127	328811	4.718914	10.63112	6.460708	7.727918	5.528909	54.313
26	4177	2200	0	344528.1	3.930396	10.00293	6.452038	7.713867	5.533393	54.232
27	4177	2300	0.0254	87745.77	3.907231	10.09589	6.429319	7.709084	5.533393	54.196
28	4177	100	0	61885.15	3.420466	9.886798	6.438287	7.709084	5.52024	54.177
29	4177	200	0.0254	50801.38	3.48996	9.979762	6.438287	7.699817	5.524425	54.052
30	4177	300	0	47106.03	3.211678	9.816998	6.438287	7.699518	5.52024	53.656
31	4177	400	0	35097.85	2.95656	9.770669	6.442771	7.695034	5.52024	53.342
32	4177	500	0	26785.02	2.771242	9.70087	6.442771	7.694735	5.516055	53.085
33	4177	600	0	24014.08	2.748077	9.607601	6.469975	7.695034	5.524425	52.86

HOURLY DATA (US-41, Sullivan County)

34	4177	700	0	12930.31	2.608783	9.561271	6.460708	7.690251	5.52024	52.632
35	4177	800	0	4617.481	2.44663	9.491777				
36	4177	900	0	5541.886	2.37683	9.491167				
37	4177	1000	0	7388.424	2.121713	9.374734				
38	4177	1100	0	7388.424	2.005889	9.281465				
39	4177	1200	0	6466.291	1.820266	9.211666				
40	4177	1300	0	6466.291	1.773631	9.211056				
41	4177	1400	0	4617.481	1.680667	9.093708				
42	4177	1500	0	5541.886	1.37922	8.55787				
43	4177	1600	0	6466.291	1.680667	8.93003				
44	4177	1700	0	5541.886	1.610868	8.859622				
45	4177	1800	0	7388.424	1.40208	8.836152				
46	4177	1900	0	7388.424	1.147267	8.720633				
47	4177	2000	0	5541.886	0.776326	8.464601				
48	4177	2100	0	6466.291	0.776326	8.674608				
49	4177	2200	0	4617.481	0.452018	8.582863				
50	4177	2300	0	5541.886	0.011582	8.560003				

HOURLY DATA (US-30, Laporte County)

TOT.HRS	RTE/CNTY	TIME	RAIN [cm]	FLOW [cm3]	HEAD1 inner [cm]	HEAD2 center [cm]	HEAD3 outer [cm]	HEAD4 subgrade [cm]	TENSION center [cm]	TENSION subgrade [cm]	TEMP subbase deg. F
1	3046	2200	0.1016	0	2.351227	1.184758	2.693822	1.442923	5.192601	5.398571	71.243
2	3046	2300	0.254	0	4.970983	8.238744	4.559808	1.46365	5.196786	5.377645	71.233
3	3046	2400	0.2032	0	8.228076	10.14374	8.123834	1.416101	5.17586	5.368976	71.162
4	3046	100	0.1778	10606.81	11.15629	9.040673	3.381756	1.414272	5.183932	5.356122	70.966
5	3046	200	0.0254	22097.13	8.749284	1.938833	1.811782	1.390498	5.196487	5.351936	70.826
6	3046	300	0	13257.37	6.719316	0.598627	0.313639	1.319784	5.209043	5.343566	70.691
7	3046	400	0	4419.881	5.0673	0.410566	1.140257	1.31887	5.209043	5.343566	70.47
8	3046	500	0	2650.566	3.793236	0.269748	1.141171	1.340815	5.217114	5.339082	70.292
9	3046	600	0	1767.044	2.447544	0.505054	1.283208	1.34051	5.229969	5.339082	70.093
10	3046	700	0	883.522	1.432255	0.034747	1.118006	1.246327	5.238339	5.334897	69.887
11	3046	800	0	883.522	-0.05517	0.011278	1.18872	1.316431	5.23804	5.326526	69.713
12	3046	900	0	883.522	1.573987	-0.31821	1.18872	1.269492	5.250894	5.322042	69.451
13	3046	1000	0	0	1.550213	-0.41239	1.118006	1.222858	5.25508	5.318156	69.274
14	3046	1100	0	883.522	1.526438	-0.55352	1.093622	1.294181	5.259265	5.313971	69.1
15	3046	1200	0	0	1.502664	-0.62454	1.092708	1.22621	5.251193	5.309786	68.928
16	3046	1300	0	0	1.478585	-0.64831	1.067105	1.370076	5.251193	5.297529	68.851
17	3046	1400	0	0	1.477975	0.126797	1.088441	1.256995	5.251492	5.293344	68.796
18	3046	1500	0	0	1.477366	0.783336	1.132942	1.309116	5.242823	5.28886	68.796
19	3046	1600	0	0	1.524305	0.665378	1.107948	1.28839	5.238937	5.284974	68.942
20	3046	1700	0	0	1.54747	0.429768	1.412748	1.267968	5.230566	5.310384	69.092
21	3046	1800	0	0	1.524	-0.06309	1.059485	1.360932	5.235051	5.314569	69.331
22	3046	1900	0	0	1.547774	-0.22708	1.061009	1.358494	5.251492	5.322939	69.611
23	3046	2000	0	0	1.548384	-0.41422	1.133551	1.143914	5.251492	5.32264	69.803
24	3046	2100	0	0	1.619707	-0.55474	1.136294	1.466698	5.272119	5.33131	69.985
25	3046	2200	0	0	1.620317	-0.67178	1.161593	1.46365	5.272119	5.327124	70.114
26	3046	2300	0	0	1.620622	-0.76566	1.139342	1.274064	5.276304	5.327124	70.182
27	3046	2400	0.3302	0	8.796528	12.3572	8.976665	1.55448	5.26345	5.297529	70.172
28	3046	100	0.1778	12373.85	8.985809	8.547811	2.20218	1.319479	5.246709	5.284675	69.838
29	.3046	200	0.254	20330.09	13.68491	14.73525	4.422343	1.458773	5.267934	5.28049	69.802
30	3046	300	0.6858	43310.75	28.58414	30.7787	6.477305	1.575511	5.28049	5.276005	69.383
31	3046	400	1.1938	57453.91	30.1432	30.7086	8.956548	2.27899	5.284675	5.26345	68.917
32	3046	500	0.1778	68060.72	28.3022	24.80615	3.172054	1.739189	5.292447	5.263151	68.592
33	3046	600	0.0762	54801.07	24.80767	18.87779	1.330452	2.138172	5.309487	5.263151	68.418
34	3046	700	0.0254	42427.22	20.74682	14.62004	0.055474	1.809598	5.322341	5.259265	68.34
35	3046	800	0	26517.02	15.74109	9.421063	1.070762	1.269492	5.347751	5.26345	68.249
36	3046	900	0	15026.69	12.05758	5.116068	1.118006	1.292962	5.360008	5.258966	68.149
37	3046	1000	0	14143.17	9.389364	2.246071	1.070762	1.434084	5.377047	5.258966	68.044
38	3046	1100	0.0254	9723.284	7.429195	2.081174	1.070458	1.317041	5.385418	5.25508	67.944
39	3046	1200	0.3302	12373.85	27.68468	29.8832	5.03621	1.787347	5.402457	5.25508	67.694
40	3046	1300	0	29167.58	19.46758	20.02597	1.069543	1.577035	5.415013	5.251193	67.389
41	3046	1400	0	18560.78	14.50939	12.73424	1.258214	1.671218	5.427867	5.251193	67.352
42	3046	1500	0.0254	14143.17	11.15751	8.171688	1.093013	1.413053	5.440722	5.246709	67.309
43	3046	1600	0.0762	12373.85	16.44487	11.08771	2.485644	1.577645	5.461947	5.251193	67.251
44	3046	1700	0	15026.69	12.76198	7.418527	1.068934	1.57795	5.465833	5.251193	67.232
45	3046	1800	0	9723.284	9.479585	3.490265	1.068324	1.438656	5.487656	5.247008	67.182
46	3046	1900	0	3536.359	6.552286	1.984858	1.06741	1.439875	5.50888	5.247008	67.157
47	3046	2000	0.0762	3536.359	4.050792	1.514551	1.043635	1.440485	5.508581	5.246709	67.133
48	3046	2100	0.762	7070.447	30.0292	30.68726	12.84092	1.159764	5.546846	5.251193	67.023
49	3046	2200	0.9652	32703.94	29.6988	30.24165	5.620817	2.61366	5.529806	5.242524	66.941
50	3046	2300	0.762	53917.55	30.03164	30.62021	5.244084	2.94132	5.547145	5.242823	66.671
51	3046	2400	1.27	72480.6	29.96154	30.50438	6.4008	3.808781	5.547145	5.243122	66.796
52	3046	100	0.2794	83970.93	29.65856	29.37937	3.994709	3.596945	5.542661	5.242823	66.725
53	3046	200	0.2032	80434.57	29.84937	26.44201	5.316931	2.892552	5.547145	5.247008	66.61
54	3046	300	0.0254	71594.81	27.20706	18.42394	1.72974	2.11775	5.551031	5.238339	66.599
55	3046	400	0	54801.07	21.66092	12.47485	0.99822	1.812646	5.551031	5.242524	66.562
56	3046	500	0	38890.87	17.39219	7.655966	0.999439	1.481938	5.563885	5.246709	66.551
57	3046	600	0	20330.09	13.04971	3.186989	1.000049	1.691945	5.576441	5.250894	66.538
58	3046	700	0	13257.37	8.683142	2.01168	0.977494	1.689811	5.588996	5.25508	66.503
59	3046	800	0	7953.969	4.74025	1.636166	0.979018	1.358494	5.622777	5.254781	66.414
60	3046	900	0	3536.359	2.37805	1.236269	0.979627	1.146048	5.631147	5.262852	66.231
61	3046	1000	0	2650.566	-0.36241	0.977494	0.979932	1.02809	5.648187	5.258667	66.099
62	3046	1100	0	2650.566	1.433474	0.860146	0.957072	1.049731	5.656856	5.262852	65.936
63	3046	1200	0	1767.044	1.433474	0.64831	0.981151	1.190244	5.673896	5.258667	65.732
64	3046	1300	0	1767.044	1.456944	0.506882	1.004011	1.238707	5.665226	5.254482	65.555
65	3046	1400	0	883.522	1.43317	0.247602	0.932383	1.239622	5.66675	5.246111	65.407

HOURLY DATA (US-31, St.Joseph County)

TOT.HRS	RTE/CNTY	TIME	RAIN [cm]	FLOW [cm3]	HEAD1 inner [cm]	HEAD2 center [cm]	HEAD3 outer [cm]	HEAD4 subgrade [cm]	TENSION center [cm]	TENSION outer [cm]	TENSION subgrade [cm]	TEMP subbase deg. °F
1	3171	100	0	0	-0.611734	0.9183624	0.7522464	3.3881568	3.3881568	5.7817512	5.3391816	80.594
2	3171	200	0	0	-0.635203	0.9424416	0.7531608	3.0117288	3.0117288	5.7817512	5.3434488	80.557
3	3171	300	0	0	-0.611429	0.8958072	0.7537704	2.65938	2.65938	5.7991248	5.3565552	80.451
4	3171	400	0	0	-0.611429	0.9192768	0.7540752	2.0961096	2.0961096	5.7948576	5.3519832	80.312
5	3171	500	0	0	-0.635203	0.9427464	0.7540752	1.5099792	1.5099792	5.8164984	5.3565552	80.172
6	3171	600	0	0	-0.587959	0.9192768	0.7306056	0.618744	0.618744	5.8122312	5.3650896	79.988
7	3171	700	0	0	-0.587959	0.9192768	0.7537704	-0.06035	-0.06035	5.8293	5.3733192	79.802
8	3171	800	0	0	-0.611429	0.9427464	0.7303008	-0.741274	-0.741274	5.855208	5.3943504	79.645
9	3171	900	0	0	-0.611429	0.9195816	0.707136	-1.586178	-1.586179	5.8463688	5.385816	79.505
10	3171	1000	0.1524	0	1.2057888	2.6831544	6.4187832	2.5402032	2.5402032	5.8207656	5.3605176	77.583
11	3171	1100	0.1778	3420.5246	-0.705612	0.8726424	0.0469392	19.426428	19.426428	5.876544	5.36448	73.971
12	3171	1200	0	853.99553	-0.587654	0.943356	0.7552944	17.597628	17.597628	5.8896504	5.3943504	76.288
13	3171	1300	0.4318	6841.0493	6.8448936	9.5240856	9.2022168	31.738824	31.738824	5.9670696	5.3562504	68.492
14	3171	1400	0.8382	17956.619	5.7122568	8.6541864	8.6355936	35.210496	35.210496	6.0935616	5.3733192	69.526
15	3171	1500	0.2032	26507.93	0.9695688	3.6466272	5.6153304	29.768597	29.768597	6.2069472	5.4748176	68.996
16	3171	1600	0.1524	17956.619	1.0162032	3.857244	5.9204352	29.718305	29.718305	6.2246256	5.5513224	69.595
17	3171	1700	0.127	17956.619	-1.53162	0.5663184	4.2446448	28.427172	28.427172	6.2288928	5.6150256	70.522
18	3171	1800	0	11115.569	-0.635203	0.8955024	-2.478634	25.637033	25.637033	6.1850016	5.6704992	72.522
19	3171	1900	0	3420.5246	-0.658978	0.8951976	0.6821424	24.182832	24.182832	6.1673232	5.7174384	73.286
20	3171	2000	0	2564.2578	-0.658978	0.9186672	0.6348984	23.268432	23.268432	8.158484	5.756148	73.71
21	3171	2100	0	853.99553	-0.658673	0.8955024	0.6586728	22.424746	22.424746	6.158484	5.7860184	74.034
22	3171	2200	0	853.99553	-0.587959	0.9427464	0.7068312	21.887383	21.887383	6.1587888	5.8076592	74.194
23	3171	2300	0	853.99553	-0.634898	0.943356	0.6605016	21.325942	21.325942	6.1542168	5.824728	74.3
24	3171	2400	0	0	-0.587654	0.9668256	0.6839712	20.974202	20.974202	6.1627512	5.8463688	74.323
25	3171	100	0	0	-0.587654	0.8964168	0.6608064	20.48256	20.48256	6.158484	5.8591704	74.381
26	3171	200	0	0	-0.587654	0.9436608	0.7083552	20.107656	20.107656	6.1627512	5.8677048	74.35
27	3171	300	0	853.99553	-0.634594	0.920496	0.6623304	19.781215	19.781215	6.1715904	5.8808112	74.304
28	3171	400	0	0	-0.611124	0.8973312	0.6388608	19.406006	19.406006	6.1715904	5.8936128	74.288
29	3171	500	0	0	-0.611124	0.9208008	0.6623304	19.007023	19.007023	6.1715904	5.9021472	74.179
30	3171	600	0	853.99553	-0.634594	0.8973312	0.6864096	18.655894	18.655894	6.1801248	5.9152536	74.127
31	3171	700	0	0	-0.610819	0.9211056	0.710184	18.327624	18.327624	6.1801248	5.923788	74.083
32	3171	800	0	0	-0.634594	0.897636	0.7104888	18.070068	18.070068	6.184392	5.9277504	73.99
33	3171	900	0	0	-0.610819	0.9211056	0.66294	17.717719	17.717719	6.1801248	5.9323224	73.835
34	3171	1000	0	0	-0.634898	0.8967216	0.5910072	17.45803	17.45803	6.188964	5.9368944	73.802
35	3171	1100	0	0	-0.658978	0.8951976	0.6821424	17.196206	17.196206	6.1761624	5.9326272	73.717
36	3171	1200	0	0	-0.635813	0.8939784	0.679704	16.935298	16.935298	6.1761624	5.92836	73.671
37	3171	1300	0	0	-0.659587	0.8924544	0.6528816	16.838066	16.838066	6.1725048	5.9332368	73.714
38	3171	1400	0	0	-0.73091	0.9147048	0.6739128	16.788384	16.788384	6.1770768	5.9292744	73.834
39	3171	1500	0	0	-0.731215	0.8668512	0.6717792	16.669207	16.669207	6.1728096	5.9292744	74.103
40	3171	1600	0	0	-0.707746	0.8665464	0.6711696	16.434511	16.434511	6.1642752	5.925312	74.4
41	3171	1700	0	0	-0.707746	0.9131808	0.6946392	16.411042	16.411042	6.1688472	5.9210448	74.776

HOURLY DATA (SR-9, Noble County)

TOT.HRS	RTE/CNTY	TIME	RAIN [cm]	FLOW [cm3]	HEAD2 center [cm]	HEAD3 outer [cm]	TENSION center [cm]	TENSION outer [cm]	TENSION subgrade [cm]	TEMP subbase deg. 'F
1	957	100	0	0	15.28938	7.155485	6.220054	4.738421	4.843272	72.093
2	957	200	1.4986	0	28.05806	15.17386	6.251448	4.746955	4.843272	71.692
3	957	300	2.2352	76609.76	26.08417	13.28501	6.269431	4.751222	4.843272	71.283
4	957	400	0.5334	13039.33	27.69078	14.7825	6.305093	4.767986	4.847539	70.75
5	957	500	0.6604	13039.33	27.59903	14.3445	6.341059	4.78475	4.843272	70.234
6	957	600	0.2032	15485.48	22.47748	12.93906	6.372454	4.79298	4.851806	69.772
7	957	700	0.0254	91279.86	23.00508	13.12316	6.40842	4.805782	4.864608	69.332
8	957	800	0.0254	171151.2	22.38573	12.68578	6.440119	4.814011	4.864608	68.979
9	957	900	0	230646.9	21.53534	12.22461	6.46237	4.818278	4.877105	68.678
10	957	1000	0	290131.4	21.30461	11.80948	6.480353	4.826508	4.885334	68.456
11	957	1100	0	342302.3	21.25492	11.62355	6.498336	4.822546	4.889602	68.255
12	957	1200	0	369194.1	21.02175	11.48395	6.498641	4.818278	4.893869	68.287
13	957	1300	0	379800.9	20.81083	11.29802	6.471514	4.814011	4.902403	68.485
14	957	1400	0	383866.4	20.68921	11.22609	6.444691	4.793285	4.898441	68.897
15	957	1500	0	381413.5	20.6374	11.15477	6.422441	4.772558	4.898441	69.527
16	957	1600	0	376530.3	20.54413	11.06211	6.381902	4.743298	4.889906	70.165
17	957	1700	0	371647	20.51944	10.87709	6.364224	4.718304	4.894478	70.81
18	957	1800	0	362675.5	20.33534	10.69299	6.341669	4.714037	4.898441	71.364
19	957	1900	0	354521.7	20.06102	10.5092	6.328258	4.705807	4.894478	71.654
20	957	2000	0	340667	19.83242	10.41745	6.332525	4.70977	4.894174	71.674
21	957	2100	0	329265.2	19.53524	10.14161	6.346241	4.717999	4.894174	71.581
22	957	2200	0	317840.8	19.28348	9.888626	6.37733	4.738726	4.898136	71.371
23	957	2300	0	305621.4	19.00916	9.681972	6.386474	4.742993	4.889906	71.234
24	957	2400	0	294219.6	18.80281	9.405823	6.395314	4.742993	4.885639	71.029
25	957	100	0	284430.5	18.71381	9.176614	6.40019	4.73903	4.881677	70.809
26	957	200	0.4826	272211.1	23.14011	13.64132	6.422136	4.751527	4.889906	70.661
27	957	300	0.4064	277094.3	27.54935	15.30035	6.453835	4.764024	4.898441	70.426
28	957	400	0.1778	291766.7	21.49693	12.42517	6.480658	4.776216	4.898136	70.088
29	957	500	0.1524	286065.8	22.69571	13.74008	6.50748	4.789018	4.893869	69.635

HOURLY DATA (SR-43, Tippecanoe County)

TOT.HRS	RTE/CNTY	TIME	RAIN [cm]	HEAD1 Inner [cm]	HEAD2 center [cm]	HEAD3 outer [cm]	HEAD4 subgrade [cm]	TENSION center [cm]	TENSION outer [cm]	TENSION subgrade [cm]	TEMP. subbase deg. °F
1	4379	100	0	-0.267	0.030785	6.804965	-0.27584	5.500116	5.831129	4.835042	87.897
2	4379	200	0	-0.28986	-0.01524	6.78241	-0.27584	5.517185	5.853074	4.830775	87.508
3	4379	300	0	-0.38191	-0.01494	6.75955	-0.32248	5.543093	5.870448	4.860341	87.062
4	4379	400	0	-0.42763	0.007925	6.736994	-0.34564	5.526024	5.870448	4.851806	86.635
5	4379	500	0	-0.51907	-0.01494	6.714439	-0.32278	5.534558	5.87502	4.843577	86.209
6	4379	600	0	-0.5651	-0.01494	6.783629	-0.29992	5.569306	5.914339	4.872838	85.781
7	4379	700	0	-0.58735	-0.06066	6.715354	-0.30023	5.564734	5.909767	4.864303	85.191
8	4379	800	0	-0.6794	-0.06066	6.715963	-0.30053	5.608015	5.971337	4.906366	84.735
9	4379	900	0	-0.6797	-0.01494	6.738214	-0.30023	5.616854	5.976214	4.906366	84.326
10	4379	1000	0	-0.70378	-0.01494	6.759854	-0.27615	5.616854	5.980786	4.90667	83.962
11	4379	1100	0	-0.68153	0.053645	6.87385	-0.20635	5.612892	5.963412	4.889906	83.968
12	4379	1200	0	-0.70653	0.0762	6.802222	-0.27432	5.582717	5.924093	4.873447	84.354
13	4379	1300	0	-0.63856	0.12192	6.777533	-0.22708	5.565648	5.889041	4.869485	85.029
14	4379	1400	0	-0.52517	0.213055	6.821424	-0.29535	5.548884	5.863133	4.865522	85.897
28	4379	300	1.3462	1.183843	4.619854	13.61999	16.91792	5.543093	5.826557	4.902403	86.589
29	4379	400	0.5842	1.207313	7.420051	14.42679	16.91975	5.582107	5.914644	4.957267	85.744
30	4379	500	0.1524	1.184758	7.879385	14.22014	17.63817	5.616854	5.984748	5.003597	84.739
31	4379	600	0	1.116178	5.975299	13.66876	15.64904	5.660441	6.01157	5.024933	84.298
32	4379	700	0	1.024128	3.978859	13.16279	14.4463	5.725973	6.095695	5.079797	83.971
33	4379	800	0	0.817778	2.716987	12.58885	13.47582	5.716829	6.14873	5.088331	83.349
34	4379	900	0.0508	1.139952	2.716987	12.33495	13.66053	5.734507	6.184392	5.130698	82.951
35	4379	1000	0	1.000658	1.338986	11.98748	12.50046	5.765292	6.27827	5.152339	82.474
36	4379	1100	0.9652	1.344778	8.106766	14.74683	22.60915	5.787238	6.305398	5.190744	81.949
37	4379	1200	0	1.229258	5.743042	13.0427	15.54998	5.787238	6.291986	5.216347	82
38	4379	1300	0.1778	1.251814	7.096354	12.83482	17.53911	5.782666	6.336792	5.24195	81.994
39	4379	1400	0.2032	1.344168	7.669987	13.20363	21.01047	5.800344	6.412992	5.259019	81.812
40	4379	1500	0.9144	1.275283	7.647432	14.60784	18.74368	5.82229	6.548323	5.31053	80.898
41	4379	1600	0	1.183234	6.592214	13.29599	16.10594	5.831129	6.503213	5.336134	81.286
42	4379	1700	0.0254	1.321308	7.441082	12.69766	16.03644	5.844235	6.489497	5.348935	81.14
43	4379	1800	0.0762	1.275283	7.142988	12.83604	17.00875	5.857342	6.548323	5.374843	80.763
44	4379	1900	0	1.229563	6.041746	12.42182	15.2272	5.883859	6.543751	5.387645	80.548
45	4379	2000	0.127	1.368552	7.442911	13.02228	19.60382	5.905805	6.647993	5.41782	80.202
46	4379	2100	0.0508	1.276807	6.800698	12.70041	16.36471	5.92775	6.675425	5.456834	79.715
47	4379	2200	0	1.207922	6.181344	12.28649	15.25433	5.954268	6.675425	5.473903	79.507
48	4379	2300	0	1.185062	5.309616	11.96431	14.76878	5.958535	6.688836	5.491277	79.255
49	4379	2400	0	1.070153	4.621378	11.78082	14.46855	5.976214	6.69798	5.50865	78.962
50	4379	100	0	0.932383	4.185818	11.66683	14.21557	6.011266	6.766255	5.534254	78.685
51	4379	200	0	0.840638	4.140403	11.52906	13.9385	6.024677	6.798259	5.564734	78.32
52	4379	300	0	0.748589	3.681374	11.39129	13.59164	6.02041	6.775399	5.569001	78.067
53	4379	400	0	0.748894	2.671267	11.25352	13.31458	6.033516	6.752539	5.595214	77.863
54	4379	500	0	0.656844	1.730045	11.2078	12.80556	6.05089	6.784238	5.612282	77.533
55	4379	600	0	0.656844	0.673913	11.09259	12.22675	6.077712	6.807403	5.629961	77.308
56	4379	700	0	0.51877	-0.22128	10.95482	11.48608	6.077712	6.816242	5.651297	77.131
57	4379	800	0	0.51877	-1.00218	10.90879	10.76828	6.081979	6.83453	5.655564	76.904
58	4379	900	0	0.472745	-1.3463	10.8396	10.14283	6.086856	6.848551	5.673547	76.724
59	4379	1000	0	0.448666	-1.73645	10.74542	9.793529	6.086856	6.867144	5.686654	76.646
60	4379	1100	0	0.423977	-1.85044	10.62655	9.511894	6.060338	6.83514	5.677814	76.714
61	4379	1200	0	0.399898	-1.80411	10.55553	9.301582	6.042965	6.794602	5.678424	77.132
62	4379	1300	0	0.512674	-1.75748	10.5281	9.20435	5.999074	6.708343	5.661355	77.865
63	4379	1400	0	0.511454	-2.21529	10.52566	9.086698	5.950915	6.640373	5.635447	78.882
64	4379	1500	0	0.55687	-2.37531	10.47841	9.108338	5.889041	6.567526	5.613502	80.126
65	4379	1600	0	0.602285	-2.12324	10.50066	8.96874	5.840578	6.490411	5.587289	81.313
66	4379	1700	0	0.55565	-2.48961	10.33851	8.782812	5.788152	6.450178	5.569915	82.301
67	4379	1800	0	0.533095	-1.22987	10.27024	8.667902	5.7531	6.418478	5.544007	83.011
68	4379	1900	0	0.48768	0.213665	10.27146	8.414918	5.7531	6.414211	5.509565	83.636
69	4379	2000	0	0.442874	0.0762	10.08918	8.162544	5.713781	6.409639	5.513527	83.932

HOURLY DATA (SR-63, Vermillion County)

TOT.HRS	RTE/CNTY	TIME	RAIN [cm]	FLOW [cm3]	HEAD1 inner [cm]	HEAD2 center [cm]	HEAD4 subgrade [cm]	TENSION center [cm]	TENSION outer [cm]	TENSION subgrade [cm]	TEMP subbase deg. °F
1	6383	1600	0	699.5495	-1.43226	-1.2765	-0.54864	6.770522	6.53095	8.003534	77.07
2	6383	1700	0	0	-1.31491	-1.25303	-0.38496	6.780276	6.563563	8.318602	76.936
3	6383	1800	0	0	-1.26858	-1.18262	-0.29078	6.789725	6.586728	8.601151	76.968
4	6383	1900	0	0	-1.24541	-1.15885	-0.24354	6.817462	6.605016	8.866632	77.015
5	6383	2000	0	0	-1.17561	-1.15824	-0.17252	6.822338	6.619037	9.129674	77.057
6	6383	2100	0	0	-1.17622	-1.111	-0.07864	6.83575	6.650736	9.379001	77.072
7	6383	2200	0	0	-1.15367	-1.06375	-0.00732	6.849466	6.655003	9.651797	76.982
8	6383	2300	0	0	-1.15397	-1.06345	0.039929	6.85861	6.669024	9.953854	76.865
9	6383	2400	0	0	-1.13111	-1.06284	0.133807	6.87324	6.669329	10.28121	76.693
10	6383	100	0	699.5495	-1.08417	-1.086	0.064313	6.882384	6.68335	10.63325	76.537
11	6383	200	0.1778	0	28.92034	30.99206	21.83648	6.444691	6.453835	7.196328	75.064
12	6383	300	0.2794	114726.1	30.00268	33.50971	43.14139	6.458712	6.495288	6.716268	75.53
13	6383	400	0.0762	361676.2	28.33634	28.06141	29.27177	6.477	6.541008	6.845808	75.57
14	6383	500	0.0254	144107.2	28.1495	19.87845	21.11898	6.513576	6.587033	6.952793	75.325
15	6383	600	0	108430.2	27.53898	14.12016	17.26509	6.541618	6.633362	7.042099	74.952
16	6383	700	0	88143.24	26.76418	11.09045	14.88369	6.573926	6.670548	7.103059	74.672
17	6383	800	0	56663.51	26.03632	9.66917	13.48313	6.60593	6.69798	7.159447	74.348
18	6383	900	0	34277.93	25.42367	8.52617	12.4081	6.62879	6.725717	7.182917	73.996
19	6383	1000	0	22385.58	24.85796	6.217006	11.68359	6.651955	6.753454	7.206691	73.668
20	6383	1100	0	16789.19	24.51933	4.440631	10.90574	6.665062	6.771132	7.210349	73.34
21	6383	1200	0	2798.198	24.13345	3.085186	10.80607	6.673596	6.779971	7.18627	73.205
22	6383	1300	0	5596.396	23.70064	1.986991	10.12241	6.674206	6.789725	7.205472	73.356
23	6383	1400	0	4197.297	23.3678	1.240536	9.863328	6.674206	6.785153	7.205777	73.706
24	6383	1500	0	5596.396	23.1264	0.819607	9.205874	6.655613	6.775704	7.219493	74.345
25	6383	1600	0	5596.396	22.74936	0.21397	9.041892	6.63702	6.752539	7.219493	75.099
26	6383	1700	0	4197.297	22.40006	-0.27402	8.764524	6.609588	6.734251	7.22437	75.927
27	6383	1800	0	4197.297	22.09861	-0.8321	8.277149	6.581851	6.701638	7.214921	76.651
28	6383	1900	0	2798.198	21.84075	-1.34447	7.927543	6.559296	6.683654	7.219798	77.241
29	6383	2000	0	1399.099	21.56033	-1.88001	7.929067	6.535826	6.673596	7.219188	77.607
30	6383	2100	0.0254	2098.649	21.28357	-1.83276	7.232294	6.521806	6.669024	7.204862	77.784
31	6383	2200	0	699.5495	21.1202	-1.66939	7.326478	6.512966	6.669329	7.200595	77.763
32	6383	2300	0	1399.099	20.91294	-1.78521	7.37616	6.513271	6.678778	7.2009	77.793
33	6383	2400	0	699.5495	20.79498	-1.99522	7.165848	6.518148	6.692798	7.191756	77.581
34	6383	100	0	0	20.58284	-2.22809	6.581851	6.527292	6.706514	7.149389	77.306
35	6383	200	0	0	20.39447	-2.50789	5.437022	6.527292	6.715963	7.144512	76.974
36	6383	300	0	0	20.39447	-2.7877	4.17576	6.540703	6.715658	7.139635	76.646
37	6383	400	0	0	20.25305	-3.25404	1.442618	6.54558	6.734251	7.13994	76.423
38	6383	500	0.7366	156699.1	28.85023	33.11347	25.31791	6.517843	6.715658	7.107022	76.149
39	6383	600	0.2286	684150.4	28.28422	30.43276	31.53156	6.550152	6.743395	7.102145	75.882
40	6383	700	0.0508	310595.4	27.62524	26.61026	30.73603	6.563868	6.761988	7.11647	75.569
41	6383	800	0	109829.3	27.20553	14.21069	28.82737	6.577889	6.794906	7.116775	75.321
42	6383	900	0	74152.25	26.6889	10.38758	27.17079	6.591605	6.813194	7.116775	74.975
43	6383	1000	0	43372.07	26.44993	8.753551	14.03604	6.596482	6.82752	7.112203	74.706
44	6383	1100	0	22385.58	25.99914	7.562698	12.8653	6.600444	6.82691	7.121042	74.462
45	6383	1200	0	7695.045	25.6157	6.137758	12.08959	6.604711	6.84977	7.106412	74.332
46	6383	1300	0	4896.847	25.32492	4.619549	11.4998	6.605321	6.854647	7.11647	74.534
47	6383	1400	0	1399.099	25.03627	3.080004	11.30899	6.5913	6.84977	7.116166	74.93
48	6383	1500	0	699.5495	24.89027	2.356409	11.63208	6.568135	6.836054	7.120738	75.496
49	6383	1600	0	0	24.48885	1.587703	10.95451	6.540398	6.817157	7.134758	76.227
50	6383	1700	0	0	24.34803	0.935736	11.25779	6.513271	6.775704	7.092696	76.889
51	6383	1800	0	0	24.14077	0.308153	11.77442	6.481267	6.752539	7.102145	77.649
52	6383	1900	0	0	23.88382	-0.27371	10.3059	6.458407	6.724802	7.106717	78.231
53	6383	2000	0	0	23.60524	-0.73914	10.70519	6.440119	6.711086	7.097573	78.623
54	6383	2100	0	0	23.22972	-1.27467	10.33242	6.430975	6.711086	7.097573	78.679
55	6383	2200	0	0	23.06635	-1.81021	10.31016	6.426403	6.701638	7.097268	78.996
56	6383	2300	0.6096	0	31.44317	34.1376	13.46119	6.40781	6.678473	7.087519	78.936

HOURLY DATA (US-36, Hendricks County)

TOT.HRS	RTE/CNT	TIME	RAIN [cm]	FLOW [cm3]	HEAD2 center [cm]	HEAD3 outer [cm]	HEAD4 subgrade [cm]	TENSION outer [cm]	TENSION center [cm]	TENSION subgrade [cm]	TEMP. subbase deg. 'F
1	3632	1600	0	43476.55	-1.23505	0.64069	19.37492	13.45966	8.2296	12.69553	40.609
2	3632	1700	0	0	-1.21188	0.687324	19.28073	13.43101	8.224723	12.67297	40.999
3	3632	1800	0	0	-1.23505	0.663854	19.11523	13.38651	8.215579	12.65743	41.357
4	3632	1900	0	0	-1.28199	0.640994	18.92808	13.35847	8.211007	12.63548	41.691
5	3632	2000	0	0	-1.23505	0.641299	18.90644	13.34719	8.201558	12.59647	41.972
6	3632	2100	0	0	-1.23505	0.665074	18.76623	13.32464	8.19211	12.56904	42.228
7	3632	2200	0.0254	0	-1.28199	0.641604	18.71899	13.26185	8.186928	12.52454	42.384
8	3632	2300	0.0254	0	-1.37526	0.079248	18.27032	13.1317	8.139378	12.44102	42.535
9	3632	2400	0.1524	0	-1.23535	7.111594	24.60711	13.16584	8.05434	12.41938	42.601
10	3632	100	0.1524	216508.3	-1.25852	8.706917	29.59821	13.10914	8.049768	12.38067	42.666
11	3632	200	0.0508	723443.2	-1.23535	7.441692	28.46558	13.04757	8.044891	12.34775	42.781
12	3632	300	0.2286	673884.2	1.732483	10.65367	32.01314	12.14567	7.90895	11.60465	42.781
13	3632	400	0	636476.5	-0.48738	7.113727	28.1114	12.18895	7.932115	11.67933	42.88
14	3632	500	0.0254	579967.4	-1.23535	4.980127	23.78385	12.61323	8.06897	12.04234	42.945
15	3632	600	0	357360.8	-1.25852	2.816936	22.27052	12.71869	8.059522	12.12403	42.996
16	3632	700	0	271279.8	-1.25852	1.650797	21.39544	12.75678	8.058912	12.16701	43.046
17	3632	800	0	217378.2	-1.23535	0.85344	20.82698	12.77386	8.054645	12.18895	43.11
18	3632	900	0	182598.3	-1.25852	0.173431	20.56668	12.79002	8.05434	12.20511	43.142
19	3632	1000	0	157382.7	-1.25852	-0.45964	20.37588	12.8019	8.059522	12.21669	43.204
20	3632	1100	0	138251.8	-1.25852	-0.97566	20.04304	12.79672	8.050073	12.22797	43.268
21	3632	1200	0	119993.2	-1.28199	0.617525	19.9202	12.79581	8.040319	12.21059	43.355
22	3632	1300	0	107819.2	-1.23505	0.640385	19.84644	12.78423	8.025994	12.18834	43.523
23	3632	1400	0	96515.12	-1.25821	0.68641	19.77116	12.74704	8.00801	12.18468	43.752
24	3632	1500	0	84343.41	-1.30515	0.639166	19.58066	12.71839	7.983931	12.15664	44.073
25	3632	1600	0	71299.54	-1.23474	0.661111	19.54957	12.69157	7.979664	12.13013	44.423
26	3632	1700	0	66082.45	-1.25821	0.660806	19.42948	12.66993	7.975397	12.09782	44.793
27	3632	1800	0	63475.03	-1.28138	0.660806	19.28805	12.64188	7.956499	12.07587	45.226
29	3632	1900	0	59995.46	-1.18811	0.684581	19.24294	12.60836	7.951622	12.05362	45.581
29	3632	2000	0	57388.05	-1.21158	0.638251	19.10364	12.57483	7.93242	12.04265	45.844
30	3632	2100	0	49563.54	-1.16495	0.68519	19.12772	12.58062	7.932725	12.01034	46.092
31	3632	2200	0	19128.59	-1.16495	0.66233	19.08353	12.55837	7.932725	12.01003	46.327
32	3632	2300	0	8694.401	-1.18842	0.662635	18.98995	12.54191	7.923276	11.99388	46.514
33	3632	2400	0	5217.095	-1.14148	0.662635	18.96648	12.53094	7.914132	11.98839	46.676
34	3632	100	0	1739.789	-1.14148	0.662635	18.91985	12.53094	7.904683	11.97224	46.765
35	3632	200	0	0	-1.18842	0.66294	18.82597	12.52515	7.895234	11.96675	46.862
36	3632	300	0	0	-1.14148	0.66294	18.62597	12.50838	7.880909	11.96675	46.946
37	3632	400	0	0	-1.14148	0.63947	18.73148	12.49771	7.876337	11.96127	46.993
38	3632	500	0	1739.789	-1.14148	0.662635	18.73087	12.49162	7.862316	11.95548	47.026
39	3632	600	0	0	-1.16495	0.662635	18.7071	12.47516	7.857439	11.94999	47.109
40	3632	700	0	0	-1.16495	0.662635	18.68272	12.46967	7.843418	11.93932	47.192
41	3632	800	0	1739.789	-1.21158	0.639166	18.65925	12.4587	7.824826	11.92835	47.257
42	3632	900	0	0	-1.25821	0.615696	18.58823	12.44224	7.815682	11.92317	47.37
43	3632	1000	0	0	-1.16495	0.66233	18.63395	12.43096	7.815377	11.89573	47.466
44	3632	1100	0	1739.789	-1.18811	0.638251	18.60743	12.40932	7.792212	11.89055	47.593
45	3632	1200	0	0	-1.16495	0.684276	18.62663	12.38311	7.783373	11.87013	47.748
46	3632	1300	0	0	-1.21158	0.613562	18.60103	12.35111	7.76539	11.84971	47.387
47	3632	1400	0	1739.788	-1.18811	0.682752	18.57329	12.33465	7.746797	11.80612	48.295
48	3632	1500	0	0	-1.21128	0.658673	18.56903	12.29106	7.728204	11.79027	48.643
49	3632	1600	0	1739.789	-1.18811	0.588264	18.52148	12.25784	7.709611	11.75248	49.035
50	3632	1700	0	0	-1.16464	0.611429	18.47271	12.2304	7.714183	11.72566	49.439
51	3632	1800	0	0	-1.14148	0.634898	18.44893	12.20876	7.705039	11.69335	49.853
52	3632	1900	0	1739.789	-1.00157	0.729082	18.47637	12.17524	7.699858	11.68207	50.148
53	3632	2000	0	3477.306	-1.11801	0.683057	18.45625	12.14262	7.695286	11.66592	50.416
54	3632	2100	0	4347.201	-1.09484	0.707136	18.38828	12.14841	7.690714	11.64488	50.64
55	3632	2200	0	6086.989	-1.11801	0.683971	18.29501	12.12647	7.672121	11.62842	50.757
56	3632	2300	0	6086.989	-1.09484	0.683971	18.31878	12.1155	7.653528	11.62324	50.878
57	3632	2400	0	5217.095	-1.04821	0.707441	18.34225	12.10361	7.643774	11.60617	50.995
58	3632	100	0	6956.884	-1.09484	0.683971	18.31848	12.09385	7.634935	11.59642	51.059
59	3632	200	0.0762	6086.989	-1.14148	0.683666	18.57786	11.91463	7.621219	11.45743	51.161
60	3632	300	1.143	1067767	8.097622	11.26327	32.59836	9.868205	7.007352	9.686849	54.141
61	3632	400	0	1230367	0.048463	6.60654	26.41732	10.65124	7.157009	10.40313	52.599
62	3632	500	0.0254	569542.3	-1.11801	3.961486	22.85299	11.40287	7.486498	11.06394	52.029
63	3632	600	0	322587.7	-1.11801	1.995221	21.93249	11.47176	7.495337	11.14776	51.849
64	3632	700	0	234757.8	-1.09484	0.965302	21.27199	11.5251	7.481621	11.17945	51.767
65	3632	800	0	187815.4	-1.07137	0.145694	21.08302	11.56838	7.500214	11.20628	51.751
66	3632	900	0	152165.6	-1.07137	-0.67361	-96.8624	11.57874	7.499909	11.23249	51.702
67	3632	1000	0	127817.7	-1.09484	0.684276	-148.837	11.60556	7.504481	11.24834	51.723
68	3632	1100	0	113036.3	-1.02474	0.707746	-103.568	11.61075	7.509053	11.26937	51.684
69	3632	1200	0	99124.81	-1.04821	0.707746	-3047970	11.58941	7.476744	11.26419	51.662
70	3632	1300	0	81733.73	-1.04821	0.73152	-3047970	11.61075	7.481316	11.26937	51.682
71	3632	1400	0	67822.24	-1.07137	0.70866	-3047970	11.61562	7.481316	11.26907	51.775
72	3632	1500	0	50431.16	-1.07168	0.686105	-3047970	11.62141	7.485888	11.29589	51.854
73	3632	1600	0	36519.67	-1.09484	0.686714	-3047970	11.63635	7.503871	11.316	51.905
74	3632	1700	0	22608.17	-1.11831	0.687324	-3047970	11.66287	7.513015	11.32088	51.88
75	3632	1800	0	15651.29	-1.16495	0.641299	-3047970	11.66927	7.51332	11.34313	51.844

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76	3632	1900	0	5217.095	-1.14178	0.641909	-3047970	11.70706	7.545934	11.36447	51.718
77	3632	2000	0	3477.306	-1.14178	0.689458	-3047970	11.7284	7.545629	11.3858	51.531
78	3632	2100	0	1739.789	-1.16525	0.689762	-3047970	11.74455	7.55965	11.41781	51.339
79	3632	2200	0	1739.789	-1.16525	0.666598	-3047970	11.77595	7.568489	11.43823	51.085
80	3632	2300	0	1739.789	-1.14178	0.713842	-3047970	11.80308	7.58251	11.46505	50.82
81	3632	2400	0	1739.789	-1.16525	0.667207	-3047970	11.82441	7.591349	11.49675	50.583
82	3632	100	0	1739.789	-1.16525	0.690677	-3047970	11.86221	7.596226	11.51809	50.322
83	3632	200	0	1739.789	-1.16525	0.667512	-3047970	11.87287	7.609942	11.55558	50.05
84	3632	300	0	1739.789	-1.16525	0.714451	-3047970	11.91616	7.619086	11.57143	49.798
85	3632	400	0	3477.306	-1.18872	0.668122	-3047970	11.94328	7.623962	11.59825	49.514
86	3632	500	0	5217.095	-1.18872	0.668122	-3047970	11.95974	7.637678	11.62507	49.299
87	3632	600	0	6086.989	-1.18872	0.668426	-3047970	11.99754	7.656271	11.64123	49.06
88	3632	700	0	6086.989	-1.18872	0.692201	-3047970	12.0076	7.651394	11.68878	48.801
89	3632	800	0	5217.095	-1.16525	0.645262	-3047970	12.04021	7.66511	11.69944	48.589
90	3632	900	0	5217.095	-1.21219	0.645566	-3047970	12.07343	7.684008	11.72718	48.342
91	3632	1000	0	5217.095	-1.23566	0.645566	-3047970	12.08959	7.68858	11.75918	48.107
92	3632	1100	0	4347.201	-1.25882	0.645262	-3047970	12.11092	7.692847	11.76955	47.872
93	3632	1200	0	4347.201	-1.23535	0.645262	-3047970	12.13287	7.688275	11.7857	47.707
94	3632	1300	0	3477.306	-1.23535	0.668426	-3047970	12.1283	7.693457	11.81892	47.552
95	3632	1400	0	5217.095	-1.28229	0.668122	-3047970	12.16091	7.702906	11.81344	47.401
96	3632	1500	0	6956.884	-1.23535	0.644042	-3047970	12.16091	7.71205	11.82959	47.333
97	3632	1600	0	1739.789	-1.25882	0.620573	-3047970	12.15542	7.707478	11.85123	47.252
98	3632	1700	0	0	-1.21188	0.644042	-3047970	12.17188	7.730642	11.85672	47.205
99	3632	1800	0	0	-1.23535	0.597103	-3047970	12.19383	7.716622	11.85672	47.169
100	3632	1900	0	0	-1.21188	0.667512	-3047970	12.2048	7.730642	11.86769	47.139
101	3632	2000	0	0	-1.21188	0.690982	-3047970	12.21029	7.744663	11.88385	47.067
102	3632	2100	0	5217.095	-1.28229	0.667817	-3047970	12.23193	7.763256	11.89452	47.002
103	3632	2200	0	7824.507	-1.23535	0.644652	-3047970	12.23742	7.763256	11.90549	46.872
104	3632	2300	0.0254	6956.884	-1.28229	0.621792	-3047970	12.23681	7.767523	11.9317	46.757
105	3632	2400	0	7824.507	-1.25882	0.645262	-3047970	12.25906	7.777277	11.93749	46.615
106	3632	100*	0Y0.0254	7824.507	-1.28229	0.621792	-3047970	12.26972	7.776972	11.93719	46.464
107	3632	200	0.0254	6956.884	-1.28229	0.668731	-3047970	12.25266	7.767523	11.95304	46.3
108	3632	300	0	6086.989	-1.28229	0.645566	-3047970	12.22583	7.762951	11.94786	46.086
109	3632	400	0	5217.095	-1.30576	0.645566	-3047970	12.22035	7.753502	11.95883	45.874
110	3632	500	0	6086.989	-1.28229	0.645566	-3047970	12.23162	7.776972	11.97011	45.706
111	3632	600	0	6086.989	-1.28229	0.645566	-3047970	12.25357	7.790993	11.97559	45.542
112	3632	700	0	6086.989	-1.28229	0.645566	-3047970	12.26942	7.809586	11.98047	45.362
113	3632	800	0	6086.989	-1.56301	0.45781	-3047970	12.2746	7.804709	12.0016	45.197
114	3632	900	0	6086.989	-1.30576	0.669036	-3047970	12.29716	7.814158	12.01857	45.063
115	3632	1000	0	5217.095	-1.30576	0.528218	-3047970	12.30295	7.819034	12.03533	44.898
116	3632	1100	0	6086.989	-1.28229	0.645262	-3047970	12.30843	7.819034	12.05149	44.781
117	3632	1200	0	5217.095	-1.30576	0.645262	-3047970	12.31422	7.819339	12.07922	44.713
118	3632	1300	0	3477.306	-1.28229	0.621487	-3047970	12.34714	7.837932	12.06276	44.665
119	3632	1400	0.0254	1739.789	-1.28229	0.621487	-3047970	12.34135	7.851953	12.06795	44.615
120	3632	1500	0.127	1739.789	-1.37587	8.270748	-3047970	12.34135	7.7724	12.01887	43.251
121	3632	1600	0.4318	281727.7	13.61511	12.11854	-3047970	12.71077	7.720889	12.27491	41.309
122	3632	1700	0.2794	0	8.330184	11.46231	-3047970	12.72235	7.68858	12.28616	42.031
123	3632	1800	0.0762	507786.6	3.114751	7.449922	-3047970	12.77234	7.707173	12.31362	42.583
124	3632	1900	0	735617.2	-0.74432	5.971642	-3047970	12.88451	7.730642	12.41877	43.223
125	3632	2000	0	439103.6	-1.32893	4.071214	-3047970	13.09146	7.763256	12.59495	43.552
126	3632	2100	0	318249.6	-1.3524	3.10896	-3047970	13.18687	7.7724	12.63335	43.549
127	3632	2200	0.0254	267804.8	-1.32893	2.21742	-3047970	13.18687	7.781849	12.65011	43.584
128	3632	2300	0	233894.8	-1.32893	1.794967	-3047970	13.18199	7.786726	12.65621	43.533
129	3632	2400	0	213031	-1.28229	1.724254	-3047970	13.21003	7.786726	12.65621	43.465
130	3632	100	0.0254	208683.8	-1.30576	2.310384	-3047970	13.19875	7.786726	12.64493	43.432
131	3632	200	0	209553.7	-1.30546	1.301496	-3047970	13.21003	7.791298	12.66718	43.416
132	3632	300	0	190422.8	-1.30546	0.363017	-3047970	13.23838	7.800746	12.70071	43.414
133	3632	400	0	144338.9	-1.3524	-0.43434	-3047970	13.2777	7.814767	12.73973	43.368
134	3632	500	0	0	-1.30576	-1.09118	-3047970	13.33439	7.823911	12.76746	43.337
135	3632	600	0	0	-1.30576	0.668426	-3047970	13.36274	7.842809	12.7955	43.27
136	3632	700	0	0	-1.28229	0.668731	-3047970	13.39078	7.847381	12.82294	43.205
137	3632	800	0	0	-1.30576	0.668731	-3047970	13.41882	7.847076	12.85565	43.123
138	3632	900	0	0	-1.30576	0.668731	-3047970	13.47003	7.875422	12.85616	43.027
139	3632	1000	0	0	-1.32893	0.669036	-3047970	13.4874	7.865974	12.91194	42.96
140	3632	1100	0	0	-1.28229	0.645566	-3047970	13.52672	7.87969	12.92291	42.849
141	3632	1200	0	0	-1.3524	0.645566	-3047970	13.55446	7.884262	12.94455	42.751
142	3632	1300	0	0	-1.28229	0.645566	-3047970	13.57701	7.907426	12.97229	42.671
143	3632	1400	0	0	-1.30576	0.669036	-3047970	13.62883	7.912303	12.97838	42.607
144	3632	1500	0	0	-1.28229	0.715975	-3047970	13.65106	7.916875	13.01161	42.509
145	3632	1600	0	0	-1.25882	0.715975	-3047970	13.67942	7.935468	13.02807	42.41
146	3632	1700	0	0	-1.3524	0.645566	-3047970	12.14641	7.341718	10.40953	42.312
147	3632	1800	0	0	-1.3524	0.69281	-3047970	5.12826	5.540654	4.669841	42.231
148	3632	1900	0	0	-1.16556	0.810463	-3047970	5.207813	5.562295	4.743602	42.104
149	3632	2000	0	0	-1.18872	0.740359	-3047970	5.041087	5.524195	4.576267	41.96
150	3632	2100	0	0	-1.25913	0.740664	-3047970	5.032858	5.53273	4.555846	41.822
151	3632	2200	0	0	-1.18902	0.765658	-3047970	5.065776	5.553761	4.565459	41.601
152	3632	2300	0	0	-1.25913	0.719633	-3047970	5.074006	5.562295	4.584192	41.365

Appendix G
Statistical Analysis Printouts

draina.in   Tue Feb 16 16:13:46 1993   1

```
data drainage;
   input pvmt $ drain $ basek y @@;
   cards;
C P 0.6 0.74
C P 0.6 1.61
C P 0.6 1.42
C P 0.6 1.84
C P 0.6 1.51
C P 0.6 1.53
C F 74 1.78
C F 74 1.54
A P 0.12 1.70
A P 0.12 1.70
A P 0.12 1.42
O F 1.2 0.13
O F 1.2 0.38
O F 1.2 0.45
O F 1.2 0.34
O F 1.2 0.45
O F 0.12 -0.62
O F 0.12 -0.29
O F 0.12 -1.0
;
title 'STATISTICAL ANALYSIS OF PAVEMENT DRAINAGE PROJECT';
proc glm;
  class pvmt drain;
  model y=pvmt drain / solution;
  lsmeans pvmt drain / stderr pdiff;
  output out=draino p=yhat r=resid;
proc plot;
  plot resid*yhat;
  plot resid*pvmt;
  plot resid*drain;
proc glm;
  class pvmt drain;
  model y = pvmt drain basek / solution;
  lsmeans pvmt drain / stderr pdiff;
  output out=drainol p=yhat1 r=resid1;
proc plot;
  plot resid1*pvmt;
  plot resid1*drain;
  plot resid1*basek='*';
  plot resid1*yhat1;
run;
```

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STATISTICAL ANALYSIS OF PAVEMENT DRAINAGE PROJECT 1
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General Linear Models Procedure
Class Level Information

Class	Levels	Values
PVMT	3	A C O
DRAIN	2	F P

Number of observations in data set = 19

STATISTICAL ANALYSIS OF PAVEMENT DRAINAGE PROJECT 2
03:44 Wednesday, January 27, 1993

General Linear Models Procedure

Dependent Variable: Y

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	11.17332368	3.72444123	19.13	0.0001
Error	15	2.92055000	0.19470333		
Corrected Total	18	14.09387368			

R-Square	C.V.	Root MSE	Y Mean
0.792779	50.41364	0.4412520	0.8752632

Source	DF	Type I SS	Mean Square	F Value	Pr > F
PVMT	2	11.10181952	5.55090976	28.51	0.0001
DRAIN	1	0.07150417	0.07150417	0.37	0.5536

STATISTICAL ANALYSIS OF PAVEMENT DRAINAGE PROJECT 3
03:44 Wednesday, January 27, 1993

General Linear Models Procedure

Dependent Variable: Y

Source	DF	Type III SS	Mean Square	F Value	Pr > F
PVMT	2	4.57029000	2.28514500	11.74	0.0009
DRAIN	1	0.07150417	0.07150417	0.37	0.5536

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		-0.238333333 B	-0.61	0.5529	0.39260685
PVMT	A	1.845000000 B	3.94	0.0013	0.46801843
	C	1.680000000 B	4.82	0.0002	0.34884034
	O	0.000000000 B	.	.	.
DRAIN	F	0.218333333 B	0.61	0.5536	0.36028075
	P	0.000000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular and a generalized inverse

```
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      was used to solve the normal equations.   Estimates followed by the
      letter 'B' are biased, and are not unique estimators of the parameters.
              STATISTICAL ANALYSIS OF PAVEMENT DRAINAGE PROJECT                4
                                            03:44 Wednesday, January 27, 1993

                        General Linear Models Procedure
                              Least Squares Means
```

PVMT	Y LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
A	1.71583333	0.31201229	0.0001	1
C	1.55083333	0.18014038	0.0001	2
O	-0.12916667	0.23830332	0.5958	3

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3
1	.	0.6047	0.0013
2	0.6047	.	0.0002
3	0.0013	0.0002	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

```
              STATISTICAL ANALYSIS OF PAVEMENT DRAINAGE PROJECT                5
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                        General Linear Models Procedure
                              Least Squares Means
```

DRAIN	Y LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	Pr > |T| H0: LSMEAN1=LSMEAN2
F	1.15500000	0.23830332	0.0002	0.5536
P	0.93666667	0.18749605	0.0002	

```
              STATISTICAL ANALYSIS OF PAVEMENT DRAINAGE PROJECT                6
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          Plot of RESID*YHAT.  Legend: A = 1 obs, B = 2 obs, etc.

RESID |
  0.5 +       B
      |       B                                                 A
      |
      |       A                                                 C    B A
  0.0 +                                                         A
      |                                                              A A
      |       A
      |
 -0.5 +
      |       A
      |                                                         A
      |
 -1.0 +       A
      |
      -+--------+--------+--------+--------+--------+--------+--------+--------+
    -0.25     0.00     0.25     0.50     0.75     1.00     1.25     1.50     1.75

                                     YHAT
```

```
   Plot of RESID*PVMT.  Legend: A = 1 obs, B = 2 obs, etc.

RESID |
  0.5 +                                                 B
      |                        A                        B
      |
      |  B                     D                        A
  0.0 +                        A
      |  A                     A
      |                                                 A
      |
 -0.5 +
      |                                                 A
      |                        A
      |
 -1.0 +                                                 A
      |
   ---+-----------------------+------------------------+--
      A                       C                        O

                             PVMT
```



```
   Plot of RESID*DRAIN.  Legend: A = 1 obs, B = 2 obs, etc.

RESID |
  0.5 +  B
      |  B                                              A
      |
      |  B                                              E
  0.0 +                                                 A
      |  A                                              A
      |  A
      |
 -0.5 +
      |  A
      |                                                 A
      |
 -1.0 +  A
      |
   ---+------------------------------------------------+--
      F                                                P

                             DRAIN
```


General Linear Models Procedure
Class Level Information

Class	Levels	Values
PVMT	3	A C O
DRAIN	2	F P

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Number of observations in data set = 19

STATISTICAL ANALYSIS OF PAVEMENT DRAINAGE PROJECT 10
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General Linear Models Procedure

Dependent Variable: Y

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	12.99865702	3.24966425	41.54	0.0001
Error	14	1.09521667	0.07822976		
Corrected Total	18	14.09387368			

R-Square	C.V.	Root MSE	Y Mean
0.922291	31.95563	0.2796958	0.8752632

Source	DF	Type I SS	Mean Square	F Value	Pr > F
PVMT	2	11.10181952	5.55090976	70.96	0.0001
DRAIN	1	0.07150417	0.07150417	0.91	0.3553
BASEK	1	1.82533333	1.82533333	23.33	0.0003

STATISTICAL ANALYSIS OF PAVEMENT DRAINAGE PROJECT 11
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General Linear Models Procedure

Dependent Variable: Y

Source	DF	Type III SS	Mean Square	F Value	Pr > F
PVMT	2	1.79637403	0.89818702	11.48	0.0011
DRAIN	1	1.81297567	1.81297567	23.18	0.0003
BASEK	1	1.82533333	1.82533333	23.33	0.0003

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		66.09216049 B	4.81	0.0003	13.73407615
PVMT	A	-64.59512346 B	-4.70	0.0003	13.75771583
	C	-65.19864198 B	-4.71	0.0003	13.84706519
	O	0.00000000 B	.	.	.
DRAIN	F	-66.83845679 B	-4.81	0.0003	13.88405834
	P	0.00000000 B	.	.	.
BASEK		0.91358025	4.83	0.0003	0.18913052

STATISTICAL ANALYSIS OF PAVEMENT DRAINAGE PROJECT 12
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General Linear Models Procedure

NOTE: The X'X matrix has been found to be singular and a generalized inverse was used to solve the normal equations. Estimates followed by the letter 'B' are biased, and are not unique estimators of the parameters.

General Linear Models Procedure
Least Squares Means

PVMT	Y LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
A	-24.3096637	5.3914595	0.0005	1
C	-24.9131823	5.4798032	0.0005	2
O	40.2854597	8.3680496	0.0003	3

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3
1	.	0.0149	0.0003
2	0.0149	.	0.0003
3	0.0003	0.0003	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

General Linear Models Procedure
Least Squares Means

DRAIN	Y LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	Pr > |T| H0: LSMEAN1=LSMEAN2
F	-36.3983572	7.7758100	0.0004	0.0003
P	30.4400996	6.1089935	0.0002	

Plot of RESID1*PVMT. Legend: A = 1 obs, B = 2 obs, etc.

```
RESID1 |
   0.5 +
       |                           A                            A
       |
       |   B                       D                            B
   0.0 +                           A                            C
       |   A                       A
       |                                                        A
       |                                                        A
  -0.5 +
       |
       |                           A
       |
  -1.0 +
       |
       ---+-----------------------+----------------------------+--
          A                       C                            O

                                 PVMT
```

```
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          Plot of RESID1*DRAIN.  Legend: A = 1 obs, B = 2 obs, etc.

        RESID1 |
           0.5 +
               |  A                                                  A
               |
               |  C                                                  E
           0.0 +  C                                                  A
               |  A                                                  A
               |  A
               |  A
          -0.5 +
               |
               |                                                     A
               |
          -1.0 +
               |
               ---+--------------------------------------------------+--
                  F                                                  P

                                        DRAIN

              STATISTICAL ANALYSIS OF PAVEMENT DRAINAGE PROJECT              17
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                  Plot of RESID1*BASEK.  Symbol used is '*'.

     RESID1 |
        0.5 +
            |  *
            |
            |  **                                                    *
        0.0 +  **
            |  *                                                     *
            |   *
            |  *
       -0.5 +
            |
            |  *
            |
       -1.0 +
            |
            ---+-------------+-------------+-------------+-------------+--
               0            20            40            60            80

                                         BASEK

NOTE: 8 obs hidden.
              STATISTICAL ANALYSIS OF PAVEMENT DRAINAGE PROJECT              18
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          Plot of RESID1*YHAT1.  Legend: A = 1 obs, B = 2 obs, etc.

RESID1 |
   0.5 +
       |          A                                              A
       |
       |                        B                                C  B A
   0.0 +          A             B                                A
       |                                                            A A
       |                        A
       |          A
```

```
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  -0.5 +
       |
       |                                                     A
       |
  -1.0 +
       |
       ---+----------+----------+----------+----------+----------+----------+--
        -1.0       -0.5        0.0        0.5        1.0        1.5        2.0

                                         YHAT1
```

COVER DESIGN BY ALDO GIORGINI